Wed. Sep 4, 2019

Hall A

Opening Ceremony

[OP] Opening Ceremony

Chair:Alaa El-Din Bekhit(University of Otago, New Zealand), Amauri Rosenthal(Embrapa Food Technology, Brazil), Dongxiao Sun-Waterhouse(NZIFST, New Zealand)
8:40 AM - 9:00 AM Hall A (Main Hall)

[OP] **Opening Ceremony**

8:40 AM - 9:00 AM

Keynote Lecture | Postharvest/Food Technology and Process Engineering

[4-0900-A] Keynote Lecture 4th

Chair:Amauri Rosenthal(Embrapa Food Technology, Brazil)
9:00 AM - 10:15 AM Hall A (Main Hall)

[4-0900-A-01] **Biotransformation in Changing World: New Challenges for Food Scientists**

*Alaa El-Din Ahmed Bekhit[1] （1. University of Otago(New Zealand)）

9:00 AM - 9:30 AM

[4-0900-A-02] **Postharvest Technology and Food Engineers' role in Agribusiness Value Chain in Africa**

*Akindele Folarin Alonge[1] （1. University of Uyo(Nigeria)）

9:30 AM - 10:00 AM

Oral Session | Postharvest/Food Technology and Process Engineering

[4-1015-A] Postharvest/Food Technology and Process Engineering (1)

Chair:Teodoro Espinosa-Solares(Universidad Autónoma Chapingo, Mexico), Daisuke Hamanaka(Kagoshima University, Japan)
10:15 AM - 12:00 PM Hall A (Main Hall)

[4-1015-A-01] **Influence of Maturity Stages on Postharvest Respiration Rate and Mechanical Properties of Peach Fruit**

Artemio Pérez-López[1], *Teodoro Espinosa-Solares[1], Sergio H Chávez-Franco[2], Carlos A Villaseñor-Perea[1], Luis H Hernández-Gómez[3], Consuelo Lobato-Calleros[1] （1. Universidad Autonoma Chapingo(Mexico), 2. Colegio de Posgraduados(Mexico), 3. Instituto Politecnico Nacional(Mexico)）

10:15 AM - 10:30 AM

[4-1015-A-02] **Application of the High Hydrostatic Pressure-Based Treatment as an Alternative for Food Retort Processing**

*Daisuke Hamanaka[1], Koki Morita[1], Taiga Kuhara[1], Kyohei Arimura[2], Yoshinori Kamitani[1] （1. Kagoshima Univ.(Japan), 2. Kagoshima Prefectural Osumi Food Technology Development center(Japan)）

10:30 AM - 10:45 AM

[4-1015-A-03] **Effect of High Voltage Electric Field on the Shelf Life of Mini Tomato Fruits**

*RAMNESH RAMNEEL KISHORE[1], Daisuke Hamanaka[1] （1. Kagoshima University(Japan)）

10:45 AM - 11:00 AM

[4-1015-A-04] **Impact of Low Electric Field on Physicochemical Properties and Antioxidant Activity of Persimmon (*Diospyros kaki*)**

Naruesorn Jaisue[1,2], Sutthiwal Setha[1,2], Daisuke Hamanaka[3], *Matchima Naradisorn[1,2] （1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai, Thailand(Thailand), 2. Research Group of Postharvest Technology, Mae Fah Luang University, Chiang Rai, Thailand(Thailand), 3. Faculty of Agriculture, Kagoshima University, Kagoshima, Japan(Japan)）

11:00 AM - 11:15 AM

[4-1015-A-05] **Effects of Ultrasound Pretreatments on the Texture and Colour Kinetics of Sweet Potato (Ipomea batatas) during Deep Fat Frying**

*Ayobami Olayemi Oladejo[1], Haile Ma[2], Cunshan Zhou[2] （1. University of Uyo, Uyo.(Nigeria), 2. Jiangsu University, Zhenjiang(China)）

11:15 AM - 11:30 AM

[4-1015-A-06] **Effect of Electromagnetic Field Pretreatment on Selected Vitamins and Fibre of Sweet Pepper and Fluted Pumpkin Leaf**

*Michael Mayokun ODEWOLE[1], Ayoola Patrick OLALUSI[2], Ajiboye Solomon OYERINDE[2], Olufunmilayo Sade OMOBA[3] （1. Department of Food Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin(Nigeria), 2. Department of Agricultural and Environmental Engineering, Federal University of Technology Akure(Nigeria), 3. Department of Food Science

and Technology, Federal University of Technology Akure(Nigeria))

11:30 AM - 11:45 AM

[4-1015-A-07] **Pulsed electric fields applications in fresh meat**

*Alaa El-Din Ahmed Bekhit[1] (1. University of otago(New Zealand))

11:45 AM - 12:00 PM

Room C

Oral Session | Food Safety

[4-1015-C] Food Safety (1)

Chair:Anthony Mutukumira(Massey University, New Zealand), siti nurjanah(Bogor Agricultural University)

10:15 AM - 12:00 PM Room C (3rd room)

[4-1015-C-01] **Surface Pasteurisation of Fresh Chicken Meat using UV-C Technology**

Arthur Jonathan Philip[1], Negah Nikanjam[1], Emilia Nowak[1], *Anthony Mutukumira[1] (1. Massey University(New Zealand))

10:15 AM - 10:30 AM

[4-1015-C-02] **Efficient Filtering of Live *Escherichia coli* by Using 60 GHz CMOS Sensor**

*Hiroki Fukuda[1], Tetsuhito Suzuki[1], Naoshi Kondo[1], Yuichi Ogawa[1] (1. Graduate School of Agriculture, Kyoto University(Japan))

10:30 AM - 10:45 AM

[4-1015-C-03] **Safety Evaluation of Bacteriocinogenic Strains of *Pediococcus acidilactici* Isolated From Artisanal Cheeses**

Luis Augusto Nero[1], Yosep Ji[2], Wilhelm Holzapfel[2], *Svetoslav Dimitrov Todorov[1] (1. Universidade Federal de Viçosa(Brazil), 2. Handong GLobal University(Korea))

10:45 AM - 11:00 AM

[4-1015-C-04] **Sensitivity Comparison of Standard and real-time PCR Assay for Detection *Salmonella* Typhimurium and Enteritidis in Indonesian Chicken Carcasses**

*siti nurjanah[1,2], Winiati Puji Rahayu[1,2], Ratih Dewanti-Hariyadi[1,2] (1. Department of Food Science &Technology, Bogor Agricultural University (IPB University)(Indonesia), 2. SEAFAST Center, Bogor Agricultural University (IPB University)(Indonesia))

11:00 AM - 11:15 AM

[4-1015-C-05] **Development of Calculation Framework for Stochastic Prediction of Uncertainty and Variability in Survival Spore Numbers during Non-isothermal Inactivation by Second-order Monte Carlo Simulation**

*Hiroki Abe[1], Kento Koyama[1], Kohei Takeoka[1], Shinya Doto[1], Shuso Kawamura[1], Shige Koseki[1] (1. Hokkaido University(Japan))

11:15 AM - 11:30 AM

[4-1015-C-06] **Evaluation Growth Characteristics of Bacterial Spores Combine Treatment with High Hydrostatic Pressure and Alkaline Electrolyzed Water**

*Koki Morita[1], Taiga Kuhara[1], Yoshinori Kamitani[1], Daisuke Hamanaka[1] (1. Kagoshima University faculty of agriculture(Japan))

11:30 AM - 11:45 AM

[4-1015-C-07] **Impact of Mechanization Development on Women and Hired Labor Utilizations of Small-Scale Rice Farming Operations in Kampar Region, Indonesia**

*UJANG PAMAN[1], Khairizal Kha, Hajry Arief Wahyudy (1. RIAU ISLAMIC UNIVERSITY(Indonesia))

11:45 AM - 12:00 PM

Room D

Oral Session | Food Quality

[4-1015-D] Food Quality (1)

Chair:Yutaka Kitamura(University of Tsukuba, Japan), Mizuki Tsuta(National Agriculture and Food Research Organization)

10:15 AM - 12:00 PM Room D (4th room)

[4-1015-D-01] **Effects of Operational Conditions of Internal Combustion Furnace on rice husk Biochar and vinegar**

*WEI-PUO KUO[1], YUTAKA KITAMURA[2], Yoshiyuki HARA[4], CHING-CHEN HSIEH[3], YI-HUNG LIN[3], CHEN-PIN CHEN[1] (1. Taiwan Agricultural Machinery and Biomechatromics Engineering Technology Development Association(Taiwan), 2. University of Tsukuba(Japan), 3. National Pingtung University of Science and Technology(Taiwan), 4. Hokkaido Agricultural Experiment Station(Japan))

10:15 AM - 10:30 AM

[4-1015-D-02] **Assessment of Red Tomato Freshness Using Ultraviolet-induced Fluorescence Image**

*Keiji Konagaya[1], Dimas Firmanda Al Riza[1], Minori Yoneda[1], Sen Nie[1], Takuya Hirata[2], Noriko Takahashi[2], Makoto Kuramoto[2], Tetsuhito Suzuki[1], Naoshi Kondo[1] （1. Kyoto Univ.(Japan), 2. Ehime Univ.(Japan)）

10:30 AM - 10:45 AM

[4-1015-D-03] **Thermal oxidation stability assessment of extra virgin olive oil using fluorescence and transmittance imaging system**

*Vincent Rotich[1], Dimas Firmanda Al Riza[1], Ferruccio Giametta[2], Tetsuhito Suzuki[1], Yuichi Ogawa[1], Naoshi Kondo[1] （1. Kyoto University(Japan), 2. University of Molise(Italy)）

10:45 AM - 11:00 AM

[4-1015-D-04] **Chalkiness Index of Sake Rice “Yamada Nishiki” Using Ultraviolet-Near-Infrared Transmission**

*Khokan Kumar Saha[1,2], Firmanda Al Riza Dimas[1], Yuichi Ogawa[1], Tetsuhito Suzuki[1], Naoshi Kondo[1], Takuma Sugimoto[3] （1. Lab of Bio-sensing Engineering,Graduate School of Agriculture, Kyoto University, Kitashirakawa-Oiwakecho,Sakyo-ku ,606-8502.(Japan), 2. Department of Agricultural Engineering, Bangabandhu Sheikh Mujubur Rahman Agricultural University,Salna,Gazipur-1706.(Bangladesh), 3. Senior Researcher, Hyogo Prefectural Agriculture, Forestry and Fisheries Technology Research Center, Addo City, Hyogo Prefecture ,671-3441.(Japan)）

11:00 AM - 11:15 AM

[4-1015-D-05] **Quantification of Tofu microstructure by image analysis**

*CHIANG WEN-HSIN[1], Yoshito SAITO[1], Kohei OGATA[1], Tetsuhito SUZUKI[1], Naoshi KONDO[1] （1. Graduate School of Agriculture, Kyoto University(Japan)）

11:15 AM - 11:30 AM

[4-1015-D-06] **Processing of Green Tea Paste by Micro Wet Milling and Quality Evaluation During Storage**

*Md Zohurul Islam[1], Yutaka Kitamura[1], Mito Kokawa[1], Shinya Fujii[2], Hisayuki Nakayama[2] （1. Graduate School of Life and Environmental Sciences, University of Tsukuba, Ibaraki, Tsukuba-shi, Japan(Japan), 2. Nagasaki Agricultural and Forestry Technical Development Center, Nagasaki, Japan(Japan)）

11:30 AM - 11:45 AM

[4-1015-D-07] **Quality Changes During Ripening of Mango (*Mangifera indica* L. ‘Nam Dok Mai’) under Different Temperature Conditions**

*Eriko Yasunaga[1], Kohei Nakano[2], Busarakorn Mahayothee[3], Pramote Khuwijitjaru[3], Shinji Fukuda[4], Wolfram Spreer[5] （1. The University of Tokyo(Japan), 2. Gifu University(Japan), 3. Silpakorn University(Thailand), 4. Tokyo University of Agriculture and Technology(Japan), 5. Hohenheim University(Germany)）

11:45 AM - 12:00 PM

Hall A

Oral Session | Postharvest/Food Technology and Process Engineering

[4-1330-A] Postharvest/Food Technology and Process Engineering (2)

Chair:Olaniyi A. Fawole(Stellenbosch University, South Africa), nutthachai pongprasert(King Mongkut's University of Technology Thonburi, Thailand)

1:30 PM - 3:30 PM Hall A (Main Hall)

[4-1330-A-01] **Edible Coatings Control Shrivel and Maintain Quality of Nectarines during Simulated Export Conditions**

Shannon Riva[2], *Olaniyi Amos Fawole[1], Umezuruike Linus Opara[1,2] （1. Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Department of Food Science, Stellenbosch University(South Africa), 2. Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Department of Horticultural Science, Stellenbosch University(South Africa)）

1:30 PM - 1:45 PM

[4-1330-A-02] **Development and Characterization of Chitosan Film Incorporated with Cashew (*Anacardium Occidentale*) Leaf Extracts**

*moooksupang - Liangpanth[1,2,3] （1. Mae Fah Luang University(Thailand), 2. Thomas

Karbowiak(France), 3. Wirongrong Tongdeesoontorn(Thailand))

1:45 PM - 2:00 PM

[4-1330-A-03] **Green Synthesis of Zinc Oxide Nanoparticles from Asiatic Pennywort (*Centella asiatica* L.) and Its Effect on the Rice Starch-Gelatin Composite Film**

*Wantida Homthawornchoo[1,2], Suttiporn Pinijsuwan[1,2], Saroat Rawdkuen[1,2] (1. School of Agro-Industry, Mae Fah Luang University(Thailand), 2. Innovative Food Packaging and Biomaterials Unit (IFP), Mae Fah Luang University,(Thailand))

2:00 PM - 2:15 PM

[4-1330-A-04] **Combination of high pressure processing and heat treatment on quality and antioxidant activity of fresh-cut persimmon**

Paweena Jarungjitaree[1], Matchima Naradisorn1[1,2], Daisuke Hamanaka [3], *Sutthiwal Setha[1,2] (1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai, 57100, Thailand(Thailand), 2. Research Group of Postharvest Technology, Mae Fah Luang University, Chiang Rai, 57100, Thailand(Thailand), 3. Faculty of Agriculture, Kagoshima University, Kagoshima, 8900065, Japan(Japan))

2:15 PM - 2:30 PM

[4-1330-A-05] **Postharvest Ethylene Application Influences Biochemical Quality of Pummelo Fruit Under Low Temperature Storage**

*Paemika Promkaew[1], Varit Srilaong[2], Satoru Kondo[1] (1. Graduate School of Horticulture, Chiba University(Japan), 2. Division of Postharvest Technology, School of Bioresources and Technology, King Mongkut's University of Technology Thonburi (Bangkhuntien)(Thailand))

2:30 PM - 2:45 PM

[4-1330-A-06] **Quality Characteristics of Thai Coconut Candy as Affected by Rice Starch-Based Film Enriched with Dragon Fruit Peel Extract**

*Wantida Homthawornchoo[1,3], Nur Fairuza Syahira Mohamad Hakimi[2,1], Saroat Rawdkuen[1,3] (1. Food Science and Technology Program, Mae Fah Luang University(Thailand), 2. Food Sciences and Technology Program, Universiti Teknologi MARA(Malaysia), 3. Innovative Food Packaging and Biomaterials Unit (IFP), Mae Fah Luang University(Thailand))

2:45 PM - 3:00 PM

[4-1330-A-07] **Antifungal Packaging for Prolonging Shelf Life of Table Grapes**

*SIRIPORN LUESUWAN[1] (1. MAE FAH LUANG UNIVERSITY(Thailand))

3:00 PM - 3:15 PM

Room C

Oral Session | Food Function/Nutrition

[4-1330-C] Functional/Wellness Foods &Nutrition (1)

Chair:Rosires Deliza(Embrapa Food Technology, Brazil)
1:30 PM - 2:30 PM Room C (3rd room)

[4-1330-C-01] **The Influence of The Front-of-Pack Nutrition Labelling Schemes on Helping Healthier Food Choices by Consumer**

*Rosires Deliza[1], Marcela Alcantara[2], Renata Vaqueiro Pereira[3], Gastón Ares[4] (1. Embrapa Food Technology(Brazil), 2. PDJ_CNPq/Embrapa Food Technology(Brazil), 3. Federal Rural University of Rio de Janeiro(Brazil), 4. Universidad de la Repúb lica(Uruguay))

1:30 PM - 1:45 PM

[4-1330-C-02] **Colour and Chemical Composition of Karasumi-like Chinook salmon (*O. tshawytscha*) Roe Relevant to its Quality**

*Senni Bunga[1,3], John Birch[1], Alan Carne[2], Alaa El-Din A Bekhit[1] (1. Departement of Food Science, University of Otago, New Zealand(New Zealand), 2. Department of Biochemistry, University of Otago, New Zealand(New Zealand), 3. Indonesia Endowment for Education (LPDP), Indonesia(Indonesia))

1:45 PM - 2:00 PM

[4-1330-C-03] **Effect of Inulin and *Carissa carandas* L. Supplementation on Physicochemical and Microbiological Properties of Frozen Yogurt**

*Kamonwan Manowan[1,2], Ni-orn Chomsri[1,2] （1. Agricultural Technology Research Institute, Rajamangala University of Technology Lanna(Thailand), 2. Faculty of Sciences and Agricultural Technology, Rajamangala University of Technology Lanna(Thailand)）

2:00 PM - 2:15 PM

[4-1330-C-04] **Utilization of Banana Agricultural Waste: Effects of Processing Conditions on Properties of Unripe Banana (*Musa Cavendish*) Pulp and Peel Flours**

*Natthawuddhi Donlao[1,2], Asia Perin[1], Nasuha Bunyameen[1] （1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai, Thailand(Thailand), 2. Innovative Food Packaging and Biomaterials Unit (IFP), Mae Fah Luang University, Thailand(Thailand)）

2:15 PM - 2:30 PM

Room D

Oral Session | Food Quality

[4-1330-D] Food Quality (2)

Chair:Nurheni Sri Palupi(Bogor Agricultural University, Indonesia)
1:30 PM - 2:30 PM Room D (4th room)

[4-1330-D-01] **Reducing Allergenicity of Soy Protein Isolate from Local Varieties of Soybean through Glycation with Lactose**

*Nurheni Sri PALUPI[1,2], Endang Prangdimurti[1,2], Didah Nur Faridah[1,2], Muhammad Hasriandy Asyhari[3] （1. Department of Food Science and Technology, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University(Indonesia), 2. Southeast Asian Food and Agricultural Science and Technology (SEAFAST) Center, Bogor Agricultural University(Indonesia), 3. Food Science Graduate Program, Graduate School, Bogor Agricultural University(Indonesia)）

1:30 PM - 1:45 PM

[4-1330-D-02] **Nutritional Quality of Fertilized and Salted Philippine Mallard Duck (*Anas platyrhynchos L.*) Eggs Consumed in Victoria, Laguna, Philippines**

*Lotis Escobin Mopera[1], Pauline Saludo[1], Floirendo Flores[1], Ma. Josie Sumague[1], Bryan Rey Oliveros[1], Wilson Tan[1] （1. Institute of Food Science and Technology, University of the Philippines Los Banos(Philippines)）

1:45 PM - 2:00 PM

[4-1330-D-03] **Efficacy of 1-methylcyclopropene (1-MCP) Post-cutting Treatment on the Storage Quality of Fresh-cut ‘Queen’ Pineapple (Ananas comosus(L.) Merr. cv. ‘Queen’)**

*Meryl Ancheta Bernardino[1], Katherine Anne Castillo Israel[1], Edralina Serrano[1], James Bryan Gandia[1], Wella Absulio[1] （1. University of the Philippines Los Banos(Philippines)）

2:00 PM - 2:15 PM

[4-1330-D-04] **Effect of Direct and Indirect Heating On Heat Stability of Goat Milk**

*Souvia Rahimah[1] （1. Universitas Padjadjaran(Indonesia)）

2:15 PM - 2:30 PM

Room C

Oral Session | Postharvest Facility

[4-1445-C] Postharvest Facility

Chair:Ahmad Al-Mallahi(Dalhousie University, Canada)
2:45 PM - 3:30 PM Room C (3rd room)

[4-1445-C-01] **The Effect of Level of Fill on Nutritional Quality of Maize in an Un-aerated Clay Silos**

*Mobolaji Omobowale[1], Jonathan Ogwumike[1] （1. University of Ibadan(Nigeria)）

2:45 PM - 3:00 PM

[4-1445-C-02] **Pod Storage and Maturity Effects on Specialty Cacao Pulp Quality**

*Jeana Cadby[1], Tetsuya Araki[1], Ian Marc Cabugsa[2] （1. University of Tokyo, Dept. Global Agricultural Sciences(Japan), 2. Ateneo de Davao University, Dept. of Chemistry(Philippines)）

3:00 PM - 3:15 PM

[4-1445-C-03] **Current Status of Monitoring Post-Harvest Potato Storage Units in Atlantic Canada**

*Ahmad Al-Mallahi[1] （1. Dalhousie University(Canada)）

3:15 PM - 3:30 PM

Room D

Oral Session | Postharvest Machinery

[4-1445-D] Postharvest Machinery

Chair:Yukiharu Ogawa(Chiba University, Japan)
2:45 PM - 3:15 PM Room D (4th room)

[4-1445-D-01] **A Numerical Procedure for Supporting Garlic Root Trimming Machines Using Deep Learning Algorithms**

*Thuyet Quoc Dang[1], Morinobu Matsuo[1,2], Takeshi Haji[1], Tetsuo Kawaide[1], Yuichi Kobayashi[1] (1. Institute of Agricultural Machinery, National Agriculture and Food Research Organization(Japan), 2. Central Region Agricultural Research Center, National Agriculture and Food Research Organization(Japan))

2:45 PM - 3:00 PM

[4-1445-D-02] **A Nondestructive Acoustic Vibration System for Apple Firmness Assessment**

*Chengqiao Ding[1], Di Cui[1] (1. Zhejiang University(China))

3:00 PM - 3:15 PM

Hall A

Oral Session | Postharvest/Food Technology and Process Engineering

[4-1600-A] Postharvest/Food Technology and Process Engineering (3)

Chair:Lotis Escobin Mopera(University of the Philippines Los Banos, Philippines), Natthawuddhi Donlao(Mae Fah Luang University, Thailand)
4:00 PM - 6:15 PM Hall A (Main Hall)

[4-1600-A-01] **Electricity Production from Xylose in Microbial Fuel Cells Started with Three Different Inoculum Sources**

*Yite Liu[1], Megumi Ueda[1], Tadashi Chosa[1], Seishu Tojo[1] (1. Tokyo University of Agriculture and Technology (Japan))

4:00 PM - 4:15 PM

[4-1600-A-02] **Biodegradable Food Packaging from Cavendish Banana (*Musa acuminata*) Peduncle Fiber**

Kittaporn Ngiwngam[1], Nor Jihan Jantan[2], *Wirongrong Tongdeesoontorn[1,3] (1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai 57100 (Thailand), 2. School of Industrial Technology, Universiti Teknologi MARA, Shah Alam, Selangor 42300 (Malaysia), 3. Research Group of Innovative Food Packaging and Biomaterials, Mae Fah Luang University, Chiang Rai, 57100 (Thailand))

4:15 PM - 4:30 PM

[4-1600-A-03] **Assessment of the Physical Characteristics of Maize (Zea mays) stored in different Positions within the Metallic Silos**

*BABATOPE ALBERT ALABADAN[1], CALLISTUS A. OKOLO[2] (1. Federal University, Oye Ekiti (Ikole Ekiti Campus)(Nigeria), 2. Federal University of Technology, Minna(Nigeria))

4:30 PM - 4:45 PM

[4-1600-A-04] **Rice Analogue: Technology for Rice Enrichment and Food Diversification**

*Lerjun Monilla Penaflor[1] (1. Food Engineering Division, Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Banos (Philippines))

4:45 PM - 5:00 PM

[4-1600-A-05] **Optimization of Process Conditions for *Batuan* [*Garcinia binucao* (Blanco) Choisy] Fruit Powder Production**

*Al Kaxier Guzman Ancheta[1], Erlinda I. Dizon[2] (1. University of the Philippines Los Banos(Philippines), 2. University of the Philippines Los Banos (Philippines))

5:00 PM - 5:15 PM

[4-1600-A-06] **Effect of Processing Conditions on Bioactive Compounds and Antioxidant Activities of Tea Infusion**

*Wei Qin[1], Sunantha Ketnawa[1], Florencio, Jr. Collado Reginio[1,2], Ryutaro Yamada[3], Takuya Araki[3], Yukiharu Ogawa[1] (1. Graduate School of Horticulture, Chiba University.(Japan), 2. Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baño s(Philippines), 3. Institute of Fruit Tree and Tea Science, NARO(Japan))

5:15 PM - 5:30 PM

[4-1600-A-07] ***In Vitro* Release Characteristics of Sugars and Hydrolysis of Starch During Simulated Digestion of Saba banana at Different Maturity Stages**

*Florencio, Jr. Collado Reginio[1,2], Wei Qin[1],

Yukiharu Ogawa[1] (1. Graduate School of Horticulture, Chiba University(Japan), 2. Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baños(Philippines))

5:30 PM - 5:45 PM

[4-1600-A-08] ***In Vitro* Examination of Starch Digestibility and Antioxidant Activities of Amaranth Grains**

*Xiaoyan Xiong[1], Florencio Jr. Collado Reginio[1,2], Sukanya Thuengtung[1], Sunantha Ketnawa[1], Yukiharu Ogawa[1] (1. Graduate School of Horticulture, Chiba University(Japan), 2. Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baño s(Philippines))

5:45 PM - 6:00 PM

[4-1600-A-09] **Effects of Cell Structure Changes of Citrus Peel on the Digestibility of Intracellular Antioxidants during *in vitro* Digestion**

*Yidi Cai[1], Yukiharu Ogawa[1] (1. Graduate School of Horticulture, Chiba University(Japan))

6:00 PM - 6:15 PM

Room C

Oral Session | Postharvest/Food Technology and Process Engineering

[4-1600-C] Postharvest/Food Technology and Process Engineering (4)

Chair:Kornkanok Aryusuk(King Mongkut's University of Technology Thonburi, Thailand), Itaru Sotome(University of Tokyo, Japan)

4:00 PM - 6:15 PM Room C (3rd room)

[4-1600-C-01] **Estimation of Moisture Loss of Cucumber during Storage using CFD Simulation based on Heat and Mass Transfer Model**

*Seong-Heon Kim[1], Chinatsu Nishihara[1], Fumina Tanaka[1], Fumihiko Tanaka[1] (1. Kyushu Univ.(Japan))

4:00 PM - 4:15 PM

[4-1600-C-02] **Screening (*in vitro*) The Inhibition Effect of Generally Recognized As Safe (GRAS) Substances on The Postharvest Fungal Pathogens and Its Modelling**

*Passakorn Kingwascharapong[1], Supatra Karnjanapratum[2], Fumina Tanaka[1], Fumihiko Tanaka[1] (1. Kyushu University(Japan), 2. King Mongkut's Institute of Technology Ladkrabang(Thailand))

4:15 PM - 4:30 PM

[4-1600-C-03] **Modeling The Ripening Behavior of Mature Green Tomato at Different Storage Temperatures**

*Drupadi Ciptaningtyas[1,2], Wakana Kagoshima[3], Rei Iida[1], Hitomi Umehara[1], Masafumi Johkan[1], Takeo Shiina[1] (1. Graduate School of Horticulture, Chiba University(Japan), 2. Faculty of Agro-industrial Technology, Universitas Padjadjaran(Indonesia), 3. Faculty of Horticulture, Chiba University(Japan))

4:30 PM - 4:45 PM

[4-1600-C-04] **Quality and Shelf-life Prediction of Fresh-cut 'Phulae' Pineapple by Using Image Analysis and Artificial Neural Networks**

*Rattapon Saengrayap[1], Mayura Dongsuea[1] (1. Postharvest Technology and Logistics Program, School of Agro-Industry, Mae Fah Luang University(Thailand))

4:45 PM - 5:00 PM

[4-1600-C-05] **Stationary Machine Vision Based Real-Time Estimation of Japanese Black Cattle Serum Vitamin A using Eye Fundus Color**

*SAMUEL OUMA OTIENO[1], Naoshi Kondo[1], Tateshi Fujiura[1], Yuichi Ogawa[1], Tetsuhito Suzuki[1], Katsuya Takenouchi[1], Hidetsugu Yoshioka[1], Moriyuki Fukushima[2], Takahiko Ohmae[3] (1. Graduate School of Agriculture, Kyoto University(Japan), 2. Hyogo Prefectural Hokubu Agricultural Institute(Japan), 3. Tajima Agricultural High school(Japan))

5:00 PM - 5:15 PM

[4-1600-C-06] **Segmentation of common scab lesion on intact potatoes using single near-infrared image**

*Dimas Firmanda Al Riza[1,2], Kazuya Yamamoto[3], Kazunori Ninomiya[3], Tetsuhito Suzuki[1], Yuichi Ogawa[1], Naoshi Kondo[1] (1. Laboratory of Biosensing Engineering, Graduate School of Agriculture, Kyoto University, Kitashirakawa 6068267, Kyoto(Japan), 2. Department of Agricultural Engineering, Faculty of Agricultural

Technology, University of Brawijaya, Jl. Veteran 65145, Malang(Indonesia), 3. Product Planning Department, Shibuya Seiki Co., Ltd. 2200, Minamiyoshida, Matsuyama, Ehime, 791-8042(Japan))

5:15 PM - 5:30 PM

[4-1600-C-07] **Myanmar Mango Maturity Prediction Based on Skin Color Using Machine Vision System**

*RULIN CHEN[1], Dimas Firmanda Al Riza[1], Thwe Thwe Tun Naw[2], Phyu Phyu Leiyi[2], Aye Aye Thwe[2], Khin Thida Myint[1], Yuichi Ogawa[1], Tetsuhito Suzuki[1], Naoshi Kondo[1] (1. Kyoto University(Japan), 2. Yezin Agricultural University(Myanmar))

5:30 PM - 5:45 PM

[4-1600-C-08] **Measurement of Chicken Eggshell Optical Properties Using Terahertz Spectroscopy**

*Alin Khaliduzzaman[1,3], Keiji Konagaya[1], Tetsuhito Suzuki[1], Ayuko Kashimori[2], Naoshi Kondo[1], Yuichi Ogawa[1] (1. Graduate School of Agriculture, Kyoto University(Japan), 2. NABEL Co., LTd.(Japan), 3. Department of Food Engineering and Technology, Sylhet Agricultural University(Bangladesh))

5:45 PM - 6:00 PM

[4-1600-C-09] **Application of LCA (Life Cycle Assessment) Methodology in Bioethanol Production from Sugar Industry Wastewater (Molasses) – A Case Study in West Java Province, Indonesia**

*Agusta Samodra Putra[1,2], Ryozo Noguchi[3], Tofael Ahamed[3] (1. Graduate School of Life and Environmental Sciences, University of Tsukuba(Japan), 2. Research Center for Chemistry, Indonesian Institute of Sciences(Indonesia), 3. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan))

6:00 PM - 6:15 PM

Room D

Oral Session | Others (including the category of JSAM and SASJ)

[4-1600-D] Other Categories (1)

Chair:Satoshi Yamamoto(Akita Prefectural University), Kikuhito Kawasue(University of Miyazaki)

4:00 PM - 6:15 PM Room D (4th room)

[4-1600-D-01] **Applicability Of Japanese Standard About The Powered Exoskeleton To Agriculture**

*Masahiro Tanaka[1], Satoru Umeno[1], Yutaka Kikuchi[1] (1. National Agriculture and Food Research Organization(Japan))

4:00 PM - 4:15 PM

[4-1600-D-02] **Research on an Intelligent Robot Eye-hand System for Harvesting Pumpkin in the Outdoor Condition**

*Liangliang Yang[1], Qian Wang[2], Yohei Hosino[1], Hiroki Ishikuro[1], Ying Cao[1] (1. Kitami Institute of Technology(Japan), 2. Ning Xia University(China))

4:15 PM - 4:30 PM

[4-1600-D-03] **Handy Type Pig Weight Estimation System Based on Random Forest Algorithm**

*Hsu Lai Wai[1], Kikuhito Kawasue[1], Khin Dagon Win[1], Kumiko Yoshida[2] (1. University of Miyazaki(Japan), 2. KOYO Plant Service(Japan))

4:30 PM - 4:45 PM

[4-1600-D-04] **Plant Disease Identification using Explainable Features with Deep Convolutional Neural Network**

*Harshana Habaragamuwa[1], Yu Oishi[1], Katu Takeya[1], Kenichi Tanaka[1] (1. National Agriculture and Food Research Organization(Japan))

4:45 PM - 5:00 PM

[4-1600-D-05] **Sensitivity and Dynamic Analysis of Microalgae Fuel Production System Using LCA**

*Riaru ISHIZAKI[1], Ryozo Noguchi[2], Agusta Samodra Putra[1], Tofael Ahamed[2], Makoto M. Watanabe[3] (1. Graduate School of Life and Environmental Sciences, University of Tsukuba(Japan), 2. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan), 3. Algae Biomass and Energy System R&D Center, University of Tsukuba(Japan))

5:00 PM - 5:15 PM

[4-1600-D-06] **An Aerial Weed Detection System for Green Onion Crops Using the You-Only-Look-Once (YOLO) Deep Learning Algorithm**

Addie Ira Borja Parico[1], *Tofael Ahamed[2] （1. College of Agrobiological Resource Sciences, School of Life and Environmental Sciences, University of Tsukuba(Japan), 2. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan)）

5:15 PM - 5:30 PM

[4-1600-D-07] **A Deep Learning and MSM Machine Learning System for Recognition of Weed Infestation in Cabbage Field Using Unmanned Aerial Vehicle**

*Tofael Ahamed[1], Yan Zhang[1], Linhuan Zhang[1], Ryozo Noguchi[1] （1. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan)）

5:30 PM - 5:45 PM

[4-1600-D-08] **Mallard Navigation Using Unmanned Ground Vehicles, Imprinting, and Feeding**

*Hirokazu Madokoro[1], Satoshi Yamamoto[1], Hanwool Woo[1], Kazuhito Sato[1] （1. Akita Prefectural University(Japan)）

5:45 PM - 6:00 PM

[4-1600-D-09] **Onion Bulb Counting in a Large-scale Field Using a Drone with RTK-GNSS**

*Satoshi Yamamoto[1], Hirokazu Madokoro[1], Yo Nishimura[1], Yukio Yaji[1] （1. Akita Prefectural University(Japan)）

6:00 PM - 6:15 PM

Poster Place

Poster Displaying

[Poster Session] Poster Displaying

11:30 AM - 12:30 PM Poster Place (Entrance Hall)

Opening Ceremony

[OP] Opening Ceremony

Chair:Alaa El-Din Bekhit(University of Otago, New Zealand), Amauri Rosenthal(Embrapa Food Technology, Brazil), Dongxiao Sun-Waterhouse(NZIFST, New Zealand)
Wed. Sep 4, 2019 8:40 AM - 9:00 AM Hall A (Main Hall)
Plenary Talk

[OP] Opening Ceremony

8:40 AM - 9:00 AM

8:40 AM - 9:00 AM (Wed. Sep 4, 2019 8:40 AM - 9:00 AM Hall A)

[OP] Opening Ceremony

Keynote Lecture | Postharvest/Food Technology and Process Engineering

[4-0900-A] Keynote Lecture 4th

Chair:Amauri Rosenthal(Embrapa Food Technology, Brazil)

Wed. Sep 4, 2019 9:00 AM - 10:15 AM Hall A (Main Hall)

[4-0900-A-01] Biotransformation in Changing World: New Challenges for Food Scientists

*Alaa El-Din Ahmed Bekhit[1] （1. University of Otago(New Zealand)）

9:00 AM - 9:30 AM

[4-0900-A-02] Postharvest Technology and Food Engineers' role in Agribusiness Value Chain in Africa

*Akindele Folarin Alonge[1] （1. University of Uyo(Nigeria)）

9:30 AM - 10:00 AM

9:00 AM - 9:30 AM (Wed. Sep 4, 2019 9:00 AM - 10:15 AM Hall A)

[4-0900-A-01] Biotransformation in Changing World: New Challenges for Food Scientists

*Alaa El-Din Ahmed Bekhit[1] (1. University of Otago(New Zealand))
Keywords: Biotransformation

Current and future production trends are focussed on minimizing waste generation by improving processing conditions and developing novel technologies that enable the use of materials that have been traditionally discarded. There are obvious economic, environmental, and in many cases nutritional benefits to be gained by transforming food waste and by-products into better utilised and value added products. However, with the diversity of by-products generated (for example ranging from soft unstable material such as fruit pulps to hard stable seafood shells and wool slips), represents a major technological challenge for both industry and researchers. Furthermore, changes in consumer attitudes toward food consumption (high protein diet, low carbohydrate diet, alternative protein, alternative food, plant-based diet and so on) creates a paradigm shift in the type and quantities of what is considered as waste or by-products. This changing trend in food production and consumption, requires food scientists to be more adaptable and have wider range of skills to meet future challenges. This presentation aims to highlight some of challenges that are faced during the transformation of food waste/by-products and discusses skills that may be required by future food scientists.

9:30 AM - 10:00 AM (Wed. Sep 4, 2019 9:00 AM - 10:15 AM Hall A)

[4-0900-A-02] Postharvest Technology and Food Engineers' role in Agribusiness Value Chain in Africa

*Akindele Folarin Alonge[1] (1. University of Uyo(Nigeria))
Keywords: Agribusiness, Value Chain, Africa

Agriculture and investment in the agribusiness space has been identified as the single greatest potential source of inclusive growth in Africa. Nigeria population is currently about 190 million. Nigeria' s population expected to be 250+ million by 2030 and over 400+ million by 2050. This requires an urgent planning and aggressive execution of programmes that will bring about growth in key elements of the economy. The government has identified agriculture as one of the areas to diversify economic to avoid decline in economic growth of the nation. Agricultural sector is the dominant sector contributing a lot to Gross domestic product and crop production remains the major driver of the sector for a large percent of nominal agriculture GDP. There is need to modernize agriculture such the dominant smallholder farmers can be motivated to do more. Innovations and technologies, value addition and good government policies will enhance productivity. Postharvest and Food Process Engineers will play a major role in helping to add value through processing, storage, packaging of the agricultural crops livestock and food produce.

Oral Session | Postharvest/Food Technology and Process Engineering

[4-1015-A] Postharvest/Food Technology and Process Engineering (1)

Chair:Teodoro Espinosa-Solares(Universidad Autónoma Chapingo, Mexico), Daisuke Hamanaka(Kagoshima University, Japan)

Wed. Sep 4, 2019 10:15 AM - 12:00 PM Hall A (Main Hall)

[4-1015-A-01] Influence of Maturity Stages on Postharvest Respiration Rate and Mechanical Properties of Peach Fruit

Artemio Pérez-López[1], *Teodoro Espinosa-Solares[1], Sergio H Chávez-Franco[2], Carlos A Villaseñor-Perea[1], Luis H Hernández-Gómez[3], Consuelo Lobato-Calleros[1] （1. Universidad Autonoma Chapingo(Mexico), 2. Colegio de Posgraduados(Mexico), 3. Instituto Politecnico Nacional(Mexico)）

10:15 AM - 10:30 AM

[4-1015-A-02] Application of the High Hydrostatic Pressure-Based Treatment as an Alternative for Food Retort Processing

*Daisuke Hamanaka[1], Koki Morita[1], Taiga Kuhara[1], Kyohei Arimura[2], Yoshinori Kamitani[1] （1. Kagoshima Univ.(Japan), 2. Kagoshima Prefectural Osumi Food Technology Development center(Japan)）

10:30 AM - 10:45 AM

[4-1015-A-03] Effect of High Voltage Electric Field on the Shelf Life of Mini Tomato Fruits

*RAMNESH RAMNEEL KISHORE[1], Daisuke Hamanaka[1] （1. Kagoshima University(Japan)）

10:45 AM - 11:00 AM

[4-1015-A-04] Impact of Low Electric Field on Physicochemical Properties and Antioxidant Activity of Persimmon (*Diospyros kaki*)

Naruesorn Jaisue[1,2], Sutthiwal Setha[1,2], Daisuke Hamanaka[3], *Matchima Naradisorn[1,2] （1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai, Thailand(Thailand), 2. Research Group of Postharvest Technology, Mae Fah Luang University, Chiang Rai, Thailand(Thailand), 3. Faculty of Agriculture, Kagoshima University, Kagoshima, Japan(Japan)）

11:00 AM - 11:15 AM

[4-1015-A-05] Effects of Ultrasound Pretreatments on the Texture and Colour Kinetics of Sweet Potato (Ipomea batatas) during Deep Fat Frying

*Ayobami Olayemi Oladejo[1], Haile Ma[2], Cunshan Zhou[2] （1. University of Uyo, Uyo.(Nigeria), 2. Jiangsu University, Zhenjiang(China)）

11:15 AM - 11:30 AM

[4-1015-A-06] Effect of Electromagnetic Field Pretreatment on Selected Vitamins and Fibre of Sweet Pepper and Fluted Pumpkin Leaf

*Michael Mayokun ODEWOLE[1], Ayoola Patrick OLALUSI[2], Ajiboye Solomon OYERINDE[2], Olufunmilayo Sade OMOBA[3] （1. Department of Food Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin(Nigeria), 2. Department of Agricultural and Environmental Engineering, Federal University of Technology Akure(Nigeria), 3. Department of Food Science and Technology, Federal University of Technology Akure(Nigeria)）

11:30 AM - 11:45 AM

[4-1015-A-07] Pulsed electric fields applications in fresh meat

*Alaa El-Din Ahmed Bekhit[1] （1. University of otago(New Zealand)）

11:45 AM - 12:00 PM

10:15 AM - 10:30 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Hall A)

[4-1015-A-01] Influence of Maturity Stages on Postharvest Respiration Rate and Mechanical Properties of Peach Fruit

Artemio Pérez-López[1], *Teodoro Espinosa-Solares[1], Sergio H Chávez-Franco[2], Carlos A Villaseñor-Perea[1], Luis H Hernández-Gómez[3], Consuelo Lobato-Calleros[1] (1. Universidad Autonoma Chapingo(Mexico), 2. Colegio de Posgraduados(Mexico), 3. Instituto Politecnico Nacional(Mexico))

Keywords: physical properties, maturity stage, respiration rate, compression load, anisotropy, apparent elasticity modulus

The objective of this work is to elucidate the influence of maturity stage of peach fruit cv. Diamante on the respiration rate and mechanical properties (compression load, strain and apparent elasticity modulus during storage at room temperature. Three maturity stages (green, middle yellow and yellow) were selected for the study. The highest respiration rate was observed for middle yellow fruits. For compressive load, mechanical properties of peach fruit tissue showed anisotropic behavior in the orientation tangential or radial directions. Peach maturity stage strongly influenced the mechanical properties of peach. The physical properties sphericity, density, bulk density, porosity, and packing coefficient of the fruit harvested at physiological maturity stage were also evaluated.

10:30 AM - 10:45 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Hall A)

[4-1015-A-02] Application of the High Hydrostatic Pressure-Based Treatment as an Alternative for Food Retort Processing

*Daisuke Hamanaka[1], Koki Morita[1], Taiga Kuhara[1], Kyohei Arimura[2], Yoshinori Kamitani[1] (1. Kagoshima Univ.(Japan), 2. Kagoshima Prefectural Osumi Food Technology Development center(Japan))

Keywords: bacterial spores, heat resistance, hydrostatic pressure, shelf life

In order to extend the shelf-life of various foods, it is seriously essential to install some appropriate sterilizing technologies. In particular, various foods expecting to be stored for a long period are required to be in almost microbial-eliminated during processing. For satisfying such requirement, typical retort treatment with 121℃ for more than 5 min has been performed in the food industry. The main microbes targeted in retort processing are spores formed by some Gram positive bacteria. Bacterial spores are known to be extremely resistant to various stresses physically and chemically as compared to vegetative cells. Most of the spores are of soil origin, which means the fact that almost all agricultural products can be regarded as being contaminated with bacterial spores. Therefore, in order to preserve processed foods including agricultural commodities for a long period of time, it is required to introduce a technique capable of effectively inactivating bacterial spores. However, the current major problem is that no appropriate method other than retort treatment can be found. So far, we have investigated the effective treatment for the reduction of heat resistance of bacterial spores mainly based on high hydrostatic pressure(HHP). In particular, it has been shown that the reduction efficiency is accelerated by the combined use with alkaline electrolyzed water(AlEW), but, any experimental trials for actual processed foods has not been conducted yet. In this study, we investigated the application possibility of HHP-based treatment for extending shelf-life of some processed foods inoculated with typical bacterial spores. *B. subtilis*, *B. cereus* and *C. sporogenes* were used as test bacteria. After aerobically and anaerobically grown with appropriate media for *Bacillus* and *Clostridium*, respectively, spores were formed on the plate medium culture. After preparation of spore suspension with its spectrophotometric absorbance at 500 nm adjusted to 1 according to the conventional

methodology, the same amount of each spore suspension was mixed to prepare a spore cocktail, then inoculated to material of the processed foods. In this experiment, hamburg and potato salad were used as test foods. The ingredients used in hamburg were minced pork, diced onion, and that in potato salad were potato and mayonnaise, respectively. No additional ingredients such as spices were used. All materials used were obtained from supermarket neighboring Kagoshima University. The material inoculated with spores was sealed in a plastic film bag with triplicate volume of sterile distilled water or AlEW, and subjected to HHP treatment. The treatment conditions were 80 MPa, 50℃ for 30 min, and the samples after treatment were prepared with hamburg and potato salad by a general cooking method. The cooked sample were heat-treated in water bath at 80℃ for 15 min, and then a storage test was conducted at 30℃. For both hamburg and potato salad, the increases in viable count of food samples treated by single HHP and HHP combined with AlEW were slower comparing with that of the untreated sample during storage. More than 2 days in storage, 4-5 logs differences were obtained between the treated and untreated sample. At the same time, gas production in sealed package of treated sample was not observed. Since the storage test was in an unaerobic state, bacterial growth was considered to be dominated by *Clostridium*, but it is considered that *Bacillus* could be also effectively inactivated considering our previous unpublished data. From the above, it was shown that the treatment based on HHP is as effective as the *in vitro* study in reducing the heat resistance of bacterial spore, and it may be possible to replace retort treatment.

Oral Session | Postharvest/Food Technology and Process Engineering
[4-1015-A] Postharvest/Food Technology and Process Engineering (1)
Wed. Sep 4, 2019 10:15 AM - 12:00 PM Hall A (Main Hall)

[4-1015-A-03] Effect of High Voltage Electric Field on the Shelf Life of Mini Tomato Fruits

*RAMNESH RAMNEEL KISHORE[1], Daisuke Hamanaka[1] (1. Kagoshima University(Japan))
Keywords: High voltage electric field, climacteric fruits, respiration rate, Tomato

High voltage electric field (HVEF) which is a non thermal food preservation technique that processes food without leaving any chemical residues and radiation is one of the emerging and a new area of research in the field of food preservation. Recent research indicates the use of HVEF on agricultural commodities reduces respiration rates of climacteric fruits, inhibit enzymatic and microbial activity which leads to extending the shelf life of fruits and vegetables. A major advantage of using high voltage food preservation technique is that it consumes low energy and prohibits the use of any chemical preservatives. The main objective of this research is to investigate the effects of HVEF on the shelf extension of mini tomato fruits. Monitoring of physiological responses and quality evaluation were performed during the storage test period of 3 weeks. The mini tomato fruit samples were obtained from a local distributor in Kagoshima and the samples were carefully graded for optimum quality to be used in this experiment. The total duration of sample analysis was 3 weeks (21 days). In the first two weeks the samples were treated to continuous electric field treatment; this was the test to study continuous effect of electric field on sample quality. On the 3rd week; the electric field was shut off and samples were analyzed for further 1 week to test the shelf life storage stability of tomato fruits post EF treatment. For EF and control treatment the total frequency of monitoring or analysis was 7 times; which is a representation of different number of day intervals over the 2 weeks period. For shelf life storage testing period the samples were analyzed over a period of 1 week. Two distinctive type of EF setup was used to study the quality attributes and respiration rate respectively. For measurement of quality attributes, the samples were placed inside a large electric field incubator (High voltage 7kV A/C- power supply (N- TeFe II) at 60Hz) for EF treatment and for control experiment another similar type incubator was used but without EF treatment. The treatment temperature was 1^0C and relative humidity was approximately 95%. The quality attributes evaluated in this study were PLM (Physiological loss of mass), TSS (total soluble solid), Brix, hardness and color properties. For respiration rate measurement (CO_2) production, 2kV aluminum parallel plate configuration electric field setup was used. The HVEF system consisted of a power source with an output voltage of 2kV (NF Corporation Japan, Model: EC750SA) with A/C- power supply (sine waveform) at a frequency of 60Hz. The samples were placed into acrylic desiccator and sealed off with an air tight lid. One end of the desiccator was connected to the air pump via flexible tube while the other end was connected to much smaller desiccator that housed the CO_2 sensor. For control, similar setup was used but without EF plates in the desiccator. The entire system was setup inside the incubator with controlled temperature and RH. Four incubators with EF setup were used, each with a corresponding temperature of 0, 1, 3, 5^0C respectively. The CO_2 production of the fruits were assessed at 10 minute intervals for 2 hours. For post EF treatment analysis, the samples were transferred inside perforated bag with gas septum attached and the bags were sealed and further stored for 1 week to study shelf life stability. The gas concentration was analyzed using a gas chromatography machine. The experiments were performed in triplicates. Analysis of the PLM indicated that in the two weeks of continuous treatment, the electric field treated samples had suppressed weight loss on D1, D2 and D3 respectively, whereas for D7 and D10 samples; the control treatment showed more reduction in weight loss. During shelf life storage period, the PLM of EF samples was significantly lower than the control treatment. On day 7, maximum weight loss was seen, however the weight

loss of EF sample was still lower compared to control 0.60 and 0.87% respectively. The total soluble solid content of HVEF treated samples were higher in concentration compared to the control in the 2 weeks of continuous treatment. Post EF treatment, the EF samples still constituted to higher Brix content overall. On the day 7 of shelf life storage the average TSS content between EF and control sample were 7.06 and 6.52 Brix respectively. The fruit firmness during 2 weeks of continuous treatment indicated that on day 4 and 7, the EF samples were a lot slightly firmer with 0.84N and 0.83N difference between EF and control sample respectively. Post EF treatment, the EF treated sample were consistently firmer throughout the 1 week storage period with an average hardness of 6.7N for EF sample and 6.5N for control.

Effect of High Voltage Electric Field on the Shelf Life of Mini Tomato Fruits.

Ramnesh Kishore[1*], Daisuke Hamanaka

Department of Food Science and Biotechnology, Faculty of Agriculture, Kagoshima University, Japan
Department of Food Science and Biotechnology, Faculty of Agriculture, Kagoshima University, Japan

*Corresponding author: ramneshkishore101@gmail.com

ABSTRACT

In this experiment two distinct type of electric field setup was used to study quality attribute and respiration rate of tomato fruit (*Solanum lycopersicum*) during 2 weeks of continuous electric field treatment and 1 week of post electric field shelf life storage testing. The main focus of this experiment is to study the effects of electric field on the shelf life stability of tomato fruit. For studying quality attribute (PLM, Brix, color & hardness), a 7kV alternating current electric field setup was used. The results of samples treated with electric field had an overall suppressed weight loss, higher concentration of °Brix and firmer texture during 1 week of shelf life testing period compared to control. The Hunters color value showed no significant difference between electric field and control samples. For measurement of respiration rate (CO_2 yield), a 2kV aluminum parallel plate setup at four temperature levels of 0, 1, 3 & 5°C was used in this experiment. During 2 weeks of continuous electric field treatment samples exposed to 5°C had significantly lower $CO_{2\ yield}$ overall. For post electric field shelf life testing, samples stored under 3°C had least CO_2 production and comparatively electric field treated sample had suppressed CO_2 gas concentration than the control sample.

Keywords:
High voltage electric field
Mini tomato
Respiration rate
Shelf life
Post electric field
CO_2 yield

1. INTRODUCTION

Food preservation processes are important in extending the shelf life of foods. Fruits and vegetables due to their high metabolic activity and water content, tend to deteriorate in their quality rapidly once they are harvested. The reason as explained by (Tucker, 1993) is due to its metabolic activity that continues to occur even after harvest, thus making most fruits highly perishable commodities. This change is irreversible thus to maintain optimum quality and safety of the commodity effective preservation measures are paramount. Many factors are responsible in spoilage of agricultural commodities after harvest. The major factors that affect food spoilage include water activity, exposure to light and oxygen, pH, temperature, microbial and chemical factors such as enzymatic activities. As stated by (Anaparti, 2019) there are several factors that act together and their collective impact results in the complete decay of the food commodity. Therefore, the need for new post-harvest preservation technologies are very important for the extension of shelf life without significant loss in quality, freshness and consumer demands.

The existing post-harvest treatment facilities offers to be effective in fruit and vegetable preserving; however each kind of treatment facility has some limitations. Modified Atmospheric Packaging (MAP), for instance uses N_2/CO_2 stable gases and at low temperature environment for fruit and vegetable preservation storage but a study by (El-Kazzaz, M.K., Sommer, N.F. & Fortlage, R.J., 1983) reported that off-odors were produced when strawberries were kept under higher CO_2 atmosphere for more than 4 days as a result of anaerobic respiration. Elevated CO_2 (10% to 40%) was found to

degrade internal color and caused a decrease in anthocyanin content of the internal tissue of strawberry (Gil, 1997). Modified atmosphere packaging can help to extend the shelf-life of strawberries but the results can be variable (Shamaila, 1992). Another commonly used preservation technique is low temperature cold storage usually above 0ºC. The conventional cold storage temperature is 5^0C or below that; but its effects can be seen as chilling injury to fruits and vegetables. Chilling injury is simply damage to fruits and vegetables caused by temperature above the freezing point (0^0C) (Grant, 2019). At these temperature, the tissues weaken because they are not able to carry out normal metabolic process. Various physiological and biochemical alterations occur in the sensitive species in response to low temperature exposure. These alterations lead to the development of a variety of chilling injury symptoms, such as surface pitting, discoloration, internal breakdown, failure to ripen, growth inhibition, wilting, loss of flavor, and decay. Further research on new techniques and technologies on improved post-harvest preservation are therefore important.

High voltage electric field (HVEF) which is a non thermal food preservation technique that processes food without leaving any chemical residues and radiation is one of the emerging and a new area of research in the field of food preservation. Recent research indicates the use of HVEF on agricultural commodities reduces respiration rates of climacteric fruits, inhibit enzymatic and microbial activity which leads to extending the shelf life of fruits and vegetables. A major advantage of using high voltage food preservation technique is that it consumes low energy and prohibits the use of any chemical preservatives. Hence use of high voltage electric field (HVEF) is one the ways that tend retain quality and freshness of fruits and vegetables without any significant loss of quality attributes. As described by (Muthukumaran, 2009) in their paper that a major advantage of this technique is that it does not cause any significant change in food temperature during processing thus increasing this technology's capability to be applied to any temperature sensitive food matrix example fruits and vegetables

Previous researches carried out in this field suggest that the use of HVEF increases the shelf life of fruits and vegetables without undesirable heat, chemical and microbial effects. According to research by (Bajgai, et al., 2005) showed that upon treatment of Wase Satsuma mandarin fruits with alternating HVEF, the results showed that the fruits inhibited the degradation of the chlorophyll and flavonoids of the peels hence retaining color and flavor.

Furthermore, Emblic fruit (*Phyllanthus emblical L*) a fruit found in South Asia popular for its high vitamin C has also been studied under HVEF. According to the article, the fruits were treated by alternating current (AC) direct current (DC) with high voltage electric field of 430kV/m for 2 hours to study the physiological loss of mass (PLM). The parameters tested were rotting, color change and Vit. C content during storage at 4, 20 and 35 ^{0}C in open and closed polyethylene pouches respectively. Based on the findings of this experiment, the results showed that alternating current (HVEF) is found to have an extended shelf life of emblic fruit. The AC HVEF treated emblic fruits when tested for their hunter color values, rotting and Vit. C content showed that HVEF treated samples were much better in quality and freshness compared with the untreated samples (Bajgai, et al., 2005).

The main aim of this study is to evaluate the effects of high voltage electric field on the on the shelf extension of mini tomato fruits. Monitoring of physiological responses and quality evaluation were performed during storage test over a 3 week period.

2. MATERIALS AND METHODS

2.1 Sample preparation

Tomato fruit (*Solanum lycopersicum*) was procured form a local distributor in Kagoshima prefecture. The sample were carefully checked and graded for optimum quality, free of any visual defects like bruises and cuts. Samples which showed signs of molds were discarded.

2.1.1 AC- HVEF experimental set up & sample treatment plan

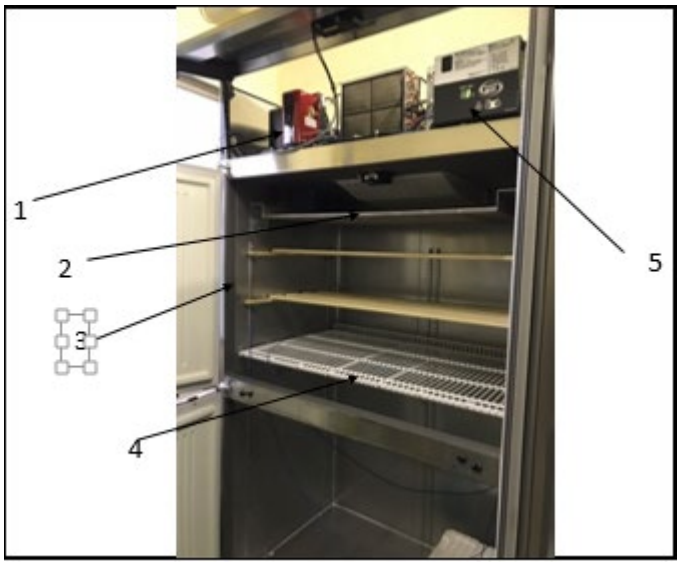

Fig. 1 HVEF setup used in measurement of quality attributes. 1; High voltage AC power supply, 2; conducting electrode, 3; incubator, 4; storage shelf, 5; temperature monitor

For measurement of quality attributes, the samples were placed inside a large electric field incubator (High voltage 7kV A/C- power supply (N- TeFe II) at 60Hz) (Figure 1) for EF treatment; and for control experiment another similar type incubator was used but without EF treatment. The treatment temperature was 1^0C and relative humidity was approximately 95%. The quality attributes evaluated in this study were PLM (Physiological loss of mass), TSS (total soluble solid), hardness and color properties. The total duration of sample analysis was 3 weeks (21 days). In the first two weeks the samples were treated to continuous electric field treatment; this was the test to study continuous effect of electric field on sample quality. On the 3rd week; the electric field was shut off and samples were analyzed for further 1 week to test the shelf life storage stability of tomato fruits post EF treatment. For EF and control treatment the total frequency of monitoring or analysis was 7 times; which is a representation of different number of day intervals (day 1,2,3,4,7,10 & 14) over the 2 weeks period. For shelf life storage testing period the samples were analyzed over a period of 1 week. The monitoring was 5 times (day 1,2,3,4 &7) in 1 week period.

2.1.2 Measurement of Physiological loss of mass (PLM)

In this experiment the cumulative loss of mass due to moisture loss of continuous electric field treated samples, post electric field shelf life test samples and control samples of tomato fruits were measured by weighing using a balance (Mettler Toledo PB3002-S, Switzerland ±0.01g). A total of 5 fruit samples were used for EF and control measurements respectively. The difference of weight for this five samples were then determined and their mean and standard deviation were calculated.

2.1.3 Measurement of Hunters Color value and total color difference

The Hunters color values units using the CIELAB ((Commission Internationale de l'Eclairage) color parameters expressed as *L* (lightness), *a* (green chromacity), and *b* (yellow chromacity) of continuous electric field treated samples, post electric field shelf life test samples and control samples of tomato fruits were measured on day 0 and on each designated day interval over 21 days of experiment period using a color meter (Minolta Chroma Meter Model CR-10 Plus (Minolta Tokyo, Japan)). For consistent reading, the fruit samples were marked at three place along the top portion of the fruit and the color reading were taken from middle part of the fruit which was just below the marked spots. Using equation 1 and CIELAB coordinate system of *L, a, b color* reading values were used to calculate the total color difference (▲*E*) (Chen, 2013). The Hunters color values reading of five samples were taken. The mean and SD of *L, a, b* values of fruit samples were determined.

$$\Delta E = \left[(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2 \right]^{1/2} \quad \text{(Eq 1)}$$

Where L_o, a_o, b_o are the initial values of fresh tomato samples on day 0 and *L, a, b* are final values

2.1.4 Measurement of Total Soluble Sugar Concentration or Brix

The total Brix content of the of continuous electric field treated samples, post electric field shelf life test samples and control samples of tomato fruits were determined by carefully slicing the fruit into

half. 1-3 drops of the tomato juice was squeezed onto the prism of the Brix meter and the readings were taken. Brix meter (Hybrid PAL-BXACID F5) model was used. The Brix readings of triplicate samples were taken. Mean and SD were then calculated.

2.1.5 Measurement of Fruit Firmness

For measurement of fruit hardness, a Rheoner II (Creep Meter PE2 330 SC) texture analyzer was used. A P79 (2mm) cylindrical needle probe was used to penetrate the fruit which was cut from the middle along the equatorial region and carefully the cut side was placed flat on base stage of the meter. The amount of force required to penetrate the fruit was recorded in Newton (N). The fruit hardness data of triplicate samples were taken and their mean and SD were calculated.

2.1.6 Measurement of Respiration rate (CO2 yield)

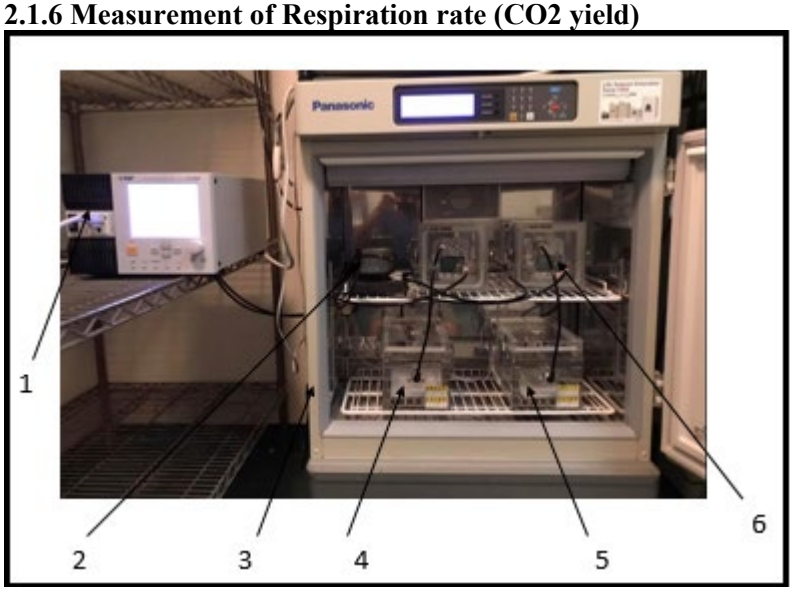

Fig. 2 HVEF setup used in measurement of respiration rate; 1; 2kV AC current power generator, 2; air pump, 3; Incubator, 4; acrylic desiccator for control treatment, 5; acrylic desiccator with parallel plate aluminum electrode, 6; smaller acrylic desiccator with CO_2 sensor.

For respiration rate measurement (CO_2) production, 2kV aluminum parallel plate configuration electric field setup was used. The HVEF system consisted of a power source with an output voltage of 2kV (NF Corporation Japan, Model: EC750SA) with A/C- power supply (sine wave) at a frequency of 60Hz. The samples were placed into acrylic desiccator and sealed off with an air tight lid. One end of the desiccator was connected to the air pump via flexible tube while the other end was connected to much smaller desiccator that housed the CO_2 sensor. For control, similar setup was used but without EF plates in the desiccator. The entire system was setup inside the incubator with controlled temperature and RH. Four incubators with EF setup were used, each with a corresponding temperature of 0, 1, 3, 5^0C respectively. The CO_2 production of the tomato fruits were measured as total gas accumulated on each day of analysis.

On day 14 the electric field was shut off. For post EF shelf life storage testing treatment, the samples were transferred inside perforated bag and the gas septum was attached on the upper side and the bags were sealed and further stored for 1 week at the same corresponding temperature of 0, 1, 3, 5^{o}C to study shelf life stability. The CO_2 gas production was analyzed using a gas chromatography machine (GC-4000 PLUS). The experiments were performed in triplicates. The mean and SD were calculated.

3. RESULTS AND DISCUSSION

3.1.1 Effect of HVEF on Physiological loss of mass of tomato fruit

Results of analysis of physiological loss of mass (PLM) of tomato fruits is shown in Table 1. The percent loss of mass as moisture loss was in a range of 0.21% to 2.12% for continuous electric filed treated sample of 2 weeks of treatment while for control treatment it was in the range of 0.31% to 2.08%. As shown by the Figure 3 the control sample had slightly higher weight loss on day 1 to day 3, however from day 4 onwards it was observed that the continuous electric field treated sample had a higher weight loss. For post electric field shelf life testing of 1 week, the results showed samples

which were treated with EF had an overall suppressed weight loss in range of 0.13- 0.60% after a week while the control samples were slightly higher in range of 0.20 – 0.80%. For both treatment types the weight loss was less than 1%. This findings suggest continuous electric treatment had a positive effect towards suppressing the weight loss of tomato fruit during shelf life test period.

Table1
Continuous effects of electric field treatment on Physiological loss of mass (of tomato fruits) treated for 2 weeks & Post EF shelf life storage test of 1 week at 1°C and 95% RH

Treatment Interval (days)	HVEF samples (%)	Control sample (%)	Treatment Interval (days)	HVEF samples (%)	Control sample (%)
	Continuous Electric Field treatment			Post EF shelf life Test	
1	0.21 ± 0.01	0.31 ± 0.10	1	0.13 ± 0.05	0.20 ± 0.04
2	0.32 ± 0.02	0.46 ± 0.10	2	0.25 ± 0.05	0.31 ± 0.04
3	0.45 ± 0.07	0.55 ± 0.09	3	0.36 ± 0.05	0.44 ± 0.03
4	0.67 ± 0.11	0.55 ± 0.09	4	0.49 ± 0.05	0.64 ± 0.04
7	1.08 ± 0.13	0.66 ± 0.26	7	0.60 ± 0.05	0.88 ± 0.09
10	1.51 ± 0.20	1.07 ± 0.03			
14	2.12 ± 0.34	2.08 ± 0.10			

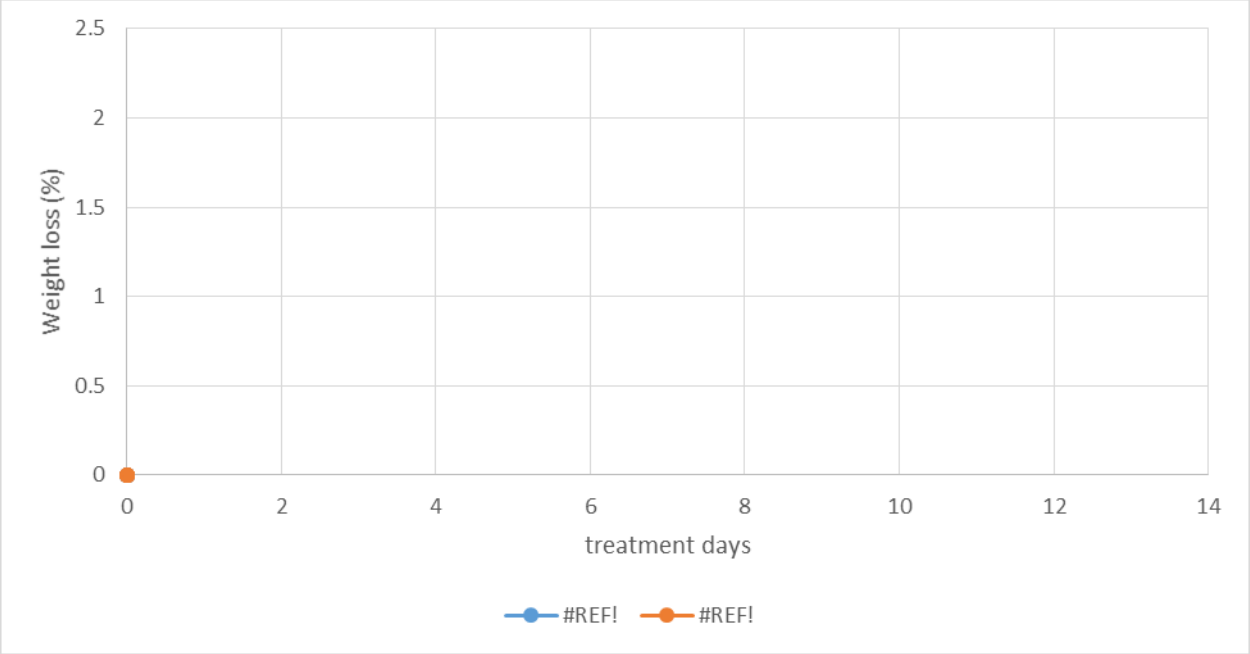

Fig 3. Physiological loss of mass of HVEF and Control samples after 14 days (1^0C; 95% RH)

3.1.2 Effect of HVEF on Hunters color value and total color change

The results from the Hunters color value of continuous electric filed treated samples and post electric field shelf life testing sample data are shown in the Table 2 & 3. For continuous EF treatment and control samples very little difference were evident between the initial and final color value (*L, a, b)* readings from day 0 to day 14. The results showed that difference between control sample and EF treated samples were very insignificant. The total color difference (▲*E*) was in range of 1.46 to 2.80 for EF samples and 0.74 to 2.97 for control samples. This value indicated fairly small difference. Except for day 10, where (▲*E*) value was maximum for both EF sample (5.72) and control (5.12) respectively. This increase in ▲*E* could have been result of some chemical or enzymatic activities that might have triggered. For post EF shelf life testing period, similar results were observed. There was very little difference between post EF treated samples and control samples except for day 7. On day 7 the total color difference was 4.61 for EF sample and 4.10 of control sample. Values in this range indicated perceptible difference between the color values.

Table2

Effects of HVEF on the Hunters color value of tomato fruit during 2 weeks continuous treatment

treatment interval	HVEF sample				Control sample			
(days)	*L*	a	b	▲*E*	*L*	a	b	▲*E*
0	-64.47 ± 2.75	11.17 ± 1.98	11.87 ± 1.81		-64.09 ± 1.86	10.92 ± 1.95	11.19 ± 1.56	
1	-61.62 ± 1.58	11.50 ± 2.13	11.96 ± 1.72	2.87	-61.22 ± 1.91	11.17 ± 2.22	10.49 ± 1.72	2.97
2	-62.75 ± 1.81	10.18 ± 2.03	11.03 ± 1.66	2.15	-62.58 ± 1.71	9.36 ± 1.84	9.33 ± 1.94	2.86
3	-62.92 ± 2.09	11.02 ± 2.53	11.76 ± 2.02	1.56	-63.95 ± 1.87	10.19 ± 1.74	10.74 ± 1.77	0.87
4	-62.44 ± 1.54	11.31 ± 2.30	11.90 ± 1.63	2.03	-62.90 ± 1.16	10.82 ± 1.87	10.86 ± 1.71	1.24
7	-63.16 ± 1.18	10.52 ± 2.15	11.78 ± 1.80	1.46	-63.66 ± 1.04	11.12 ± 1.92	11.76 ± 1.66	0.74
10	-60.17 ± 0.93	8.95 ± 1.74	8.82 ± 1.04	5.72	-60.34 ± 0.86	9.00 ± 1.53	8.06 ± 1.34	5.25
14	-62.88 ± 1.14	10.56 ± 1.81	12.01 ± 1.73	1.70	-62.94 ± 1.24	10.21 ± 1.65	11.35 ± 1.61	1.35

Table 3

Effects of HVEF on the Hunters color value of tomato fruit during 1 week post RF treatment shelf life test

treatment interval	HVEF sample				Control sample			
(days)	*L*	a	b	▲*E*	*L*	a	b	▲*E*
1	-62.12 ± 1.06	10.31 ± 1.64	10.68 ± 1.61	1.55	-63.03 ± 1.13	10.54 ± 1.68	11.29 ± 1.43	0.34
2	-62.53 ± 1.16	10.73 ± 2.00	12.20 ± 1.67	0.43	-62.22 ± 1.58	11.52 ± 1.81	12.65 ± 1.79	1.98
3	-61.82 ± 1.27	11.10 ± 1.93	12.63 ± 1.72	1.34	-62.28 ± 1.09	10.89 ± 1.69	11.72 ± 1.46	1.02
4	-60.06 ± 1.04	9.11 ± 1.74	10.03 ± 1.44	3.74	-59.68 ± 0.82	9.62 ± 1.77	9.85 ± 1.58	3.65
7	-59.21 ± 1.04	9.02 ± 1.54	9.68 ± 1.63	4.61	-59.42 ± 0.70	9.26 ± 1.29	9.48 ± 1.16	4.10

3.1.3 Effect of HVEF on Total Soluble Sugar, TSS (°Brix)

High °Brix concentration were observed for continuous electric field sample treatment for most days during the 2 weeks of treatment when compared with control (as shown in Figure 4). The TSS content of electric field samples were in range of 6.48 to 6.78 °Brix while control was in range of 6.41 to 6.87 °Brix. However on day 1 and 3 the control samples had slightly higher °Brix content of 6.79 and 6.87 °Brix. For post electric field shelf life testing period the electric field treated sample °Brix was overall higher with highest value recorded on day 7 of 7.06 compared to control. As shown in Figure 5 a continuous increase in °Brix content trend was seen with electric field sample whilst control sample °Brix showed a fluctuating trend.

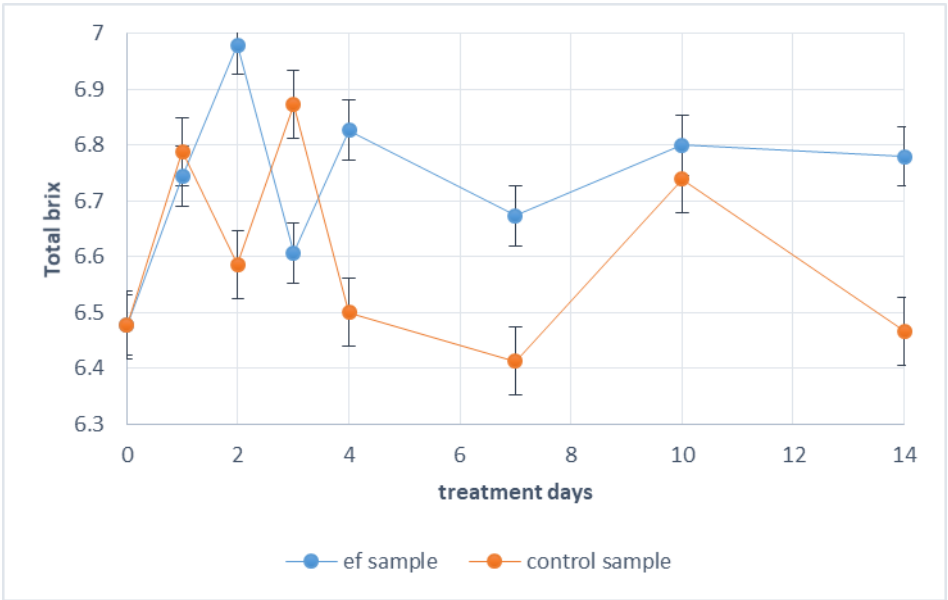

Fig. 4 Measured Brix values of continuous HVEF and control samples of 14 days of storage period (1^0C; 95% RH)

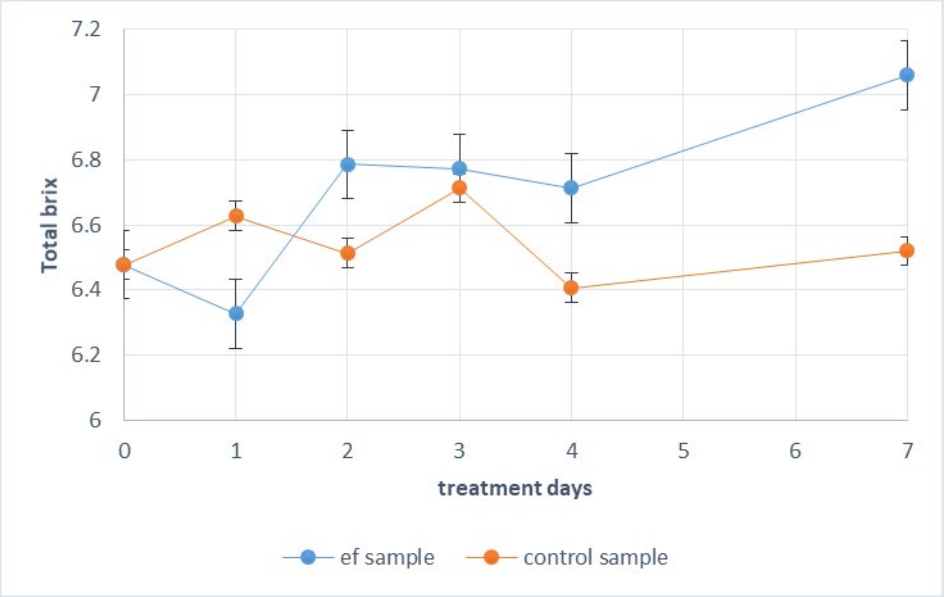

Fig. 5 Measured Brix values of post HVEF treatment and control samples of 7 days of shelf life storage testing period (1^0C; 95% RH)

3.1.4 Effect of HVEF on fruit firmness

Evaluating firmness is one of the important characteristic to determine the fruit texture and degree of ripeness or maturity of fruits and vegetables. Results from continuous electric field treatment as shown by Figure 6 indicated that electric field treatment did not have a significant effect on the fruit firmness. Overall the control sample tend to had more firm fruit texture except on day 4 and 7 where the EF treated samples were slightly firmer. The highest EF sample was 5.37N on day 4 while for control (5.87N) was the highest on day 2. For post electric field shelf life testing period the EF treated sample showed more firmness overall however the difference in firmness level was only slight compared to the control.

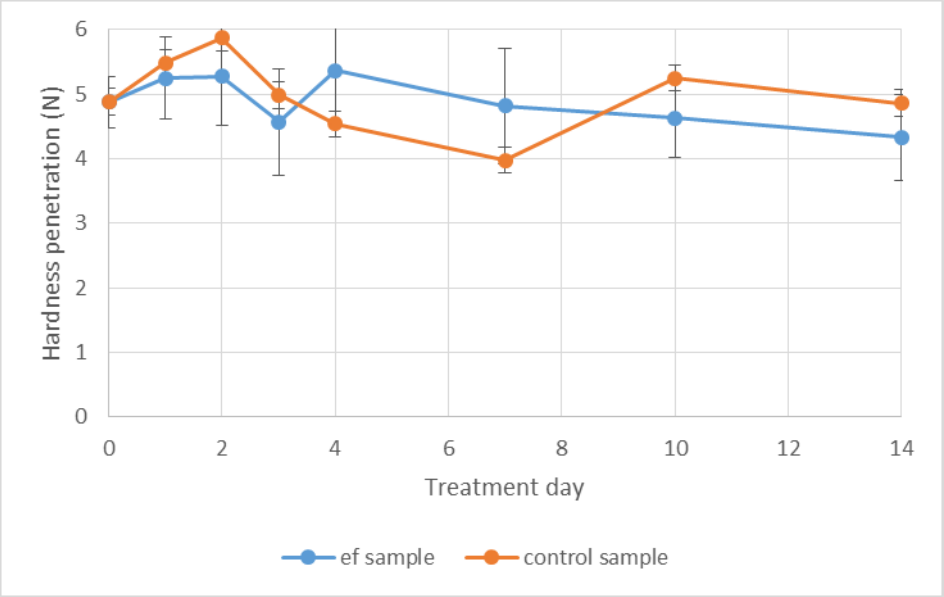

Fig.6 Fruit firmness level (N) of continuous HVEF and control samples of 14 days of storage.

3.1.5 Effect of HVEF on fruit respiration (CO_2 yield).

According to (Chi-En Liu., 2017) the rate at which the carbon dioxide gas is produced from the fruit can be used as an important physical parameter to determine the ripeness level of a fruit. In addition as described by (Bhande, 2008) that the rate at which the CO_2 gas produced has a direct impact on the life span of the fruit after harvesting. Its also described that CO_2 level is a good indicator of shelf life as the higher the rate of CO_2 production; the shorter is the shelf life. In this experiment the CO_2 production was measured by allowing CO_2 gas to accumulate inside the air tight dessicator. The CO_2 level was measured every morning corresponding to the planned monitoring schedule during the 2 weeks of continuous treatment.

As shown by Figure 7, samples stored under 1°C had the highest production of CO_2 gas recorded followed by samples stored under 0°C for both the EF treated sample and the control. Samples that were stored under 3°C was found to be in medium range of CO_2 production. The least CO_2 yield was seen for sample stored under 5°C. The samples stored under 5°C had significantly lower CO_2 production overall. Observations under this treatment temperature, shows that samples treated to continuous electric field treatment had slightly high CO_2 production compared to control.

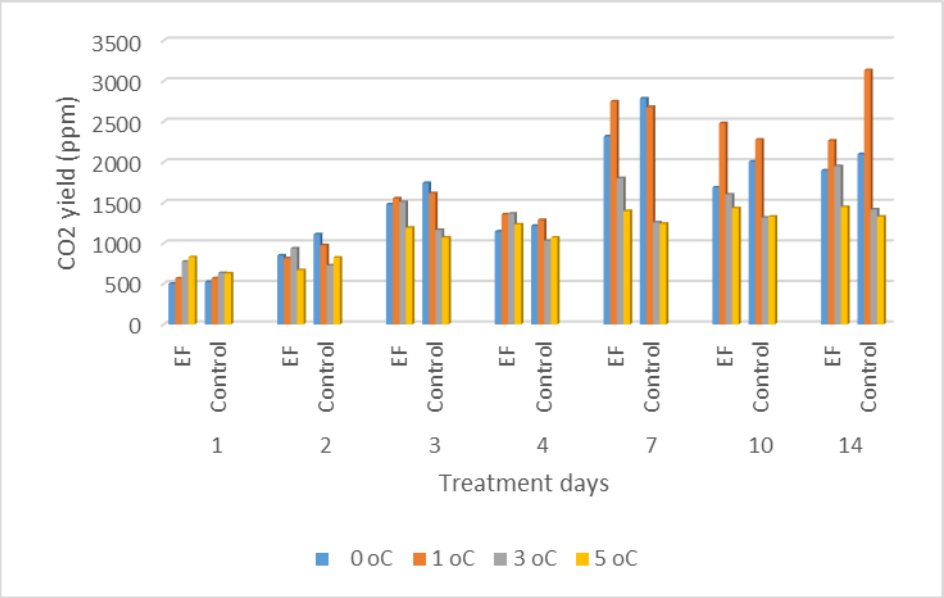

Fig 7 Carbon dioxide yield in ppm during 2 weeks of continuous electric field treatment

Post electric field treatment samples (Figure 8) that were stored under 3°C showed least percent of CO_2 production. It was also very clearly evident that samples exposed to continuous electric field treatment had suppressed CO_2 yield on all of the days. Similar trends were also observed with samples stored at 0°C and 1°C respectively.

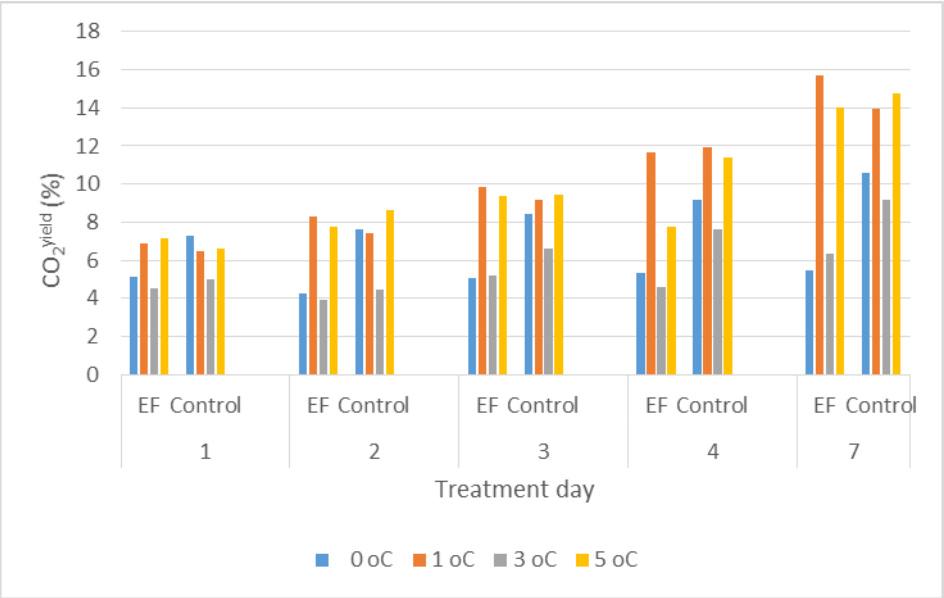

Fig 8 Carbon dioxide yield in % during 1 weeks of post electric field shelf life testing period

4. CONCLUSION

In conclusion 2 distinct type of electric field set up was used to study quality attributes and respiration rate on the shelf life extension of tomato fruits. The quality attributes were measured using a 7kV large incubator while the respiration was measured using 2kV aluminum parallel plate setup. The results showed that both type of electric field set up has a positive effect on extending the shelf life of tomato fruits. The 7kV electric field treated samples showed suppressed weight loss, firmer texture and higher Brix level during shelf life storage period. For Respiration results it was seen that at 3°C the CO_2 was least during 1 week shelf life testing of electric field treated samples. It can be said that HVEF is effective in maintaining tomato fruits quality and freshness.

ACKNOWLEDGMENT

Start from here. I would like to acknowledge Dr. Daisuke Hamanaka for providing all the technical expertise and supervision in this experiment.

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11:00 AM - 11:15 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Hall A)

[4-1015-A-04] Impact of Low Electric Field on Physicochemical Properties and Antioxidant Activity of Persimmon (*Diospyros kaki*)

Naruesorn Jaisue[1,2], Sutthiwal Setha[1,2], Daisuke Hamanaka[3], *Matchima Naradisorn[1,2] (1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai, Thailand(Thailand), 2. Research Group of Postharvest Technology, Mae Fah Luang University, Chiang Rai, Thailand(Thailand), 3. Faculty of Agriculture, Kagoshima University, Kagoshima, Japan(Japan))

Keywords: Electric field, Non-thermal technology, Persimmon, Total phenolic content, Antioxidant activity

Electric field technology is a mild preservation technology that has been recently applied to maintain nutritional and physicochemical properties of food products; and improve juice yield and polyphenol extraction in fruits. In fresh fruit, high electric field treatment showed its efficacy in suppressing respiration rate of pear, plum and banana; and delaying ripening of mature green banana and sweet pepper. However, electric field with high voltage affects texture of some fruits and vegetables by causing loss of turgor and crack of cell membranes. The use of low electric field (LEF) may be of interest as an effective tool to maintain postharvest quality of fresh fruits without causing defects. The aim of this study was to investigate the effect of low electric field (LEF) on physicochemical properties and antioxidant activity of persimmon (*Diospyros kaki*). Persimmon fruit were exposed to electric field strength of 7 kV/cm during storage at 10 ° C. Persimmons stored at 10 ° C without LEF treatment were used as a control. Analyses were performed at 3-day intervals during storage. The results showed that the firmness of persimmon fruit treated with LEF during storage for 9 days were significantly higher ($P < 0.05$) than those in the non-LEF storage condition. Exposure of LEF for 3 and 9 days significantly increased ($P < 0.05$) total phenolic content and antioxidant activity in persimmons. There was no significant difference in weight loss, colour (L^*, a^*, b^* values) and respiration rate among LEF-treated and untreated persimmons. After 15 days of storage, application of the LEF treatment for 9 days prior to storage at 10 °C significantly increased ($P < 0.05$) total phenolic content in pulp and peel by 55.76% and 41.09%, respectively, in comparison to the non-LEF treatment. This study suggests that exposure to low electric field strength during storage may be useful for prolonging shelf life of persimmon; and for producing and preserving persimmon product with high total phenolic content and antioxidant capacity.

11:15 AM - 11:30 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Hall A)

[4-1015-A-05] Effects of Ultrasound Pretreatments on the Texture and Colour Kinetics of Sweet Potato (Ipomea batatas) during Deep Fat Frying

*Ayobami Olayemi Oladejo[1], Haile Ma[2], Cunshan Zhou[2] (1. University of Uyo, Uyo.(Nigeria), 2. Jiangsu University, Zhenjiang(China))

Keywords: frying, ultrasound, kinetics, texture, colour, sweet potato

The effects of ultrasound pretreatment prior to frying on the texture and colour kinetics of deep fat fried sweet potato were investigated. Three different pretreatment methods (UD-ultrasound with distilled water, OD-Osmotic dehydration without ultrasound and UOD-ultrasound assisted osmotic dehydration) and the untreated (control) were employed in the experiment. Pretreated and untreated samples were fried in a deep

fat fryer at 130-170 °C for 2-10 min. The kinetic models for texture and colour fitted the experimental data with high coefficient of determination (> 0.700). The normalized maximum force (F*) of samples pretreated by UD showed no significant difference with that of the untreated, while samples pretreated by UOD and OD were significantly higher than that of the untreated. The rate of hardening process was significantly enhanced in sweet potato pretreated by UOD and OD during frying. For colour, samples pretreated by UOD showed high lightness (L/L_o), low redness (a/a_o), moderate yellowness (b/b_o) and low total colour difference ($\Delta E/\Delta E_o$) compared to other pretreatment methods at 150 °C. The rate of formation of lightness and yellowness of fried sweet potato was enhanced in samples pretreated by UOD. The texture and colour kinetics of pretreated and untreated fried samples were temperature dependent and expressed as activation energy. Therefore, ultrasound pretreatment is a good technology that could be applied to positively influence the texture and colour of sweet potato during deep fat frying.

Oral Session | Postharvest/Food Technology and Process Engineering
[4-1015-A] Postharvest/Food Technology and Process Engineering (1)
Wed. Sep 4, 2019 10:15 AM - 12:00 PM Hall A (Main Hall)

[4-1015-A-06] Effect of Electromagnetic Field Pretreatment on Selected Vitamins and Fibre of Sweet Pepper and Fluted Pumpkin Leaf

*Michael Mayokun ODEWOLE[1], Ayoola Patrick OLALUSI[2], Ajiboye Solomon OYERINDE[2], Olufunmilayo Sade OMOBA[3] (1. Department of Food Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin(Nigeria), 2. Department of Agricultural and Environmental Engineering, Federal University of Technology Akure(Nigeria), 3. Department of Food Science and Technology, Federal University of Technology Akure(Nigeria))

Keywords: Fluted Pumpkin Leaf, Magnetic Field, Nutrients, Electromagnetism, Sweet Pepper, Pretreatment, Blanching

Sweet pepper (SP) and Fluted pumpkin leaf (FPL) are vegetables that contain vitamins and fibre. SP has contents that cure lung cancer, diabetes, cataracts, rheumatism, arthritis, fever, cold, sores and bruises. FPL can improve hematological parameters, has anti-inflammatory and anticholesterolemic properties. Thermal pretreatment (heat addition) of vegetables during processing has the tendency of reducing their qualities. One of the promising non-thermal methods of pretreatment that is novel/emerging/non-conventional is the use of Magnetic Field (MF); however, the method is still grossly underutilized. Therefore, the effect of electromagnetic field types (static, pulse and alternating), magnetic field strength (5–30 mT) and pretreatment time (5-25 min) on the vitamins (C and A) and fibre of SP and FPL were investigated. An existing, but new electromagnetic field pretreatment device was used to conduct the experiment designed with Design Expert software (6.0.6 version). All electromagnetic field pretreated samples, controls (blanched and fresh) were analyzed in for vitamin C, vitamin A and fibre. Results showed that most of the electromagnetic field pretreatment retained/improved the vitamins (C and A) and fibre better than blanching. Vitamin C of SP and FPL are 73 - 85 mg/100g and 60 - 61.50 mg/100g for the electromagnetic field pretreatment and the blanched was 71 and 60 mg/100g for SP and FPL respectively. Vitamin A of SP and FPL were 0.0058 - 0.008 mg/100g and 0.002 mg/100g – 0.003 mg/100g for the electromagnetic field pretreatment, but blanched samples had about 0.001 mg/100g. Electromagnetic field pretreatment caused the fibre of SP and FPL to be between 1.7- 2.6% and 6 - 10% and blanched to be 1.8 and about 7% respectively. Results indicated `that electromagnetic field pretreatment of vegetables is a possible replacement alternative for blanching.

Effect of Electromagnetic Field Pretreatment on Selected Vitamins and Fibre of Sweet Pepper and Fluted Pumpkin Leaf

Michael Mayokun ODEWOLE[1*], Ayoola Patrick OLALUSI[2], Ajiboye Solomon OYERINDE[2], Olufunmilayo Sade OMOBA[3]

[1]Department of Food Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin, Nigeria
[2]Department of Agricultural and Environmental Engineering, Federal University of Technology Akure, Nigeria
[3]Department of Food Science and Technology, Federal University of Technology Akure, Nigeria

*Corresponding author: odewole2005@yahoo.com

ABSTRACT

Sweet pepper (SP) and Fluted pumpkin leaf (FPL) are vegetables that contain vitamins and fibre. SP has contents that cure lung cancer, diabetes, cataracts, rheumatism, arthritis, fever, cold, sores and bruises. FPL can improve hematological parameters, has anti-inflammatory and anticholesterolemic properties. Thermal pretreatment (heat addition) of vegetables during processing has the tendency of reducing their qualities. One of the promising non-thermal methods of pretreatment that is novel/emerging/non-conventional is the use of Magnetic Field (MF); however, the method is still grossly underutilized. Therefore, the effect of electromagnetic field types (static, pulse and alternating), magnetic field strength (5–30 mT) and pretreatment time (5-25 min) on the vitamins (C and A) and fibre of SP and FPL were investigated. An existing, but new electromagnetic field pretreatment device was used to conduct the experiment designed with Design Expert software (6.0.6 version). All electromagnetic field pretreated samples, controls (blanched and fresh) were analyzed in for vitamin C, vitamin A and fibre. Results showed that most of the electromagnetic field pretreatment retained/improved the vitamins (C and A) and fibre better than blanching. Vitamin C of SP and FPL are 73 - 85 mg/100g and 60 - 61.50 mg/100g for the electromagnetic field pretreatment and the blanched was 71 and 60 mg/100g for SP and FPL respectively. Vitamin A of SP and FPL were 0.0058 - 0.008 mg/100g and 0.002 mg/100g – 0.003 mg/100g for the electromagnetic field pretreatment, but blanched samples had about 0.001 mg/100g. Electromagnetic field pretreatment caused the fibre of SP and FPL to be between 1.7- 2.6% and 6 - 10% and blanched to be 1.8 and about 7% respectively. Results indicated `that electromagnetic field pretreatment of vegetables is a possible replacement alternative for blanching.

Keywords: Fluted Pumpkin Leaf, Magnetic Field, Nutrients, Electromagnetism, Sweet pepper, Pretreatment, Blanching

1. INTRODUCTION

Sweet pepper (SP) and fluted pumpkin leaf (FPL) are vegetables scientifically referred to as *Capsicum annum* and *Telfairia occidentalis* respectively. They both contain vitamins, fibres and other nutrients needed for growth, development and maintenance of human body. Some reported health benefits of sweet pepper are its ability to cure the following ailments: lung cancer, arthritis, diabetes, cataracts, rheumatism, fever and cold (Odewole and Olaniyan, 2015). Fluted pumpkin leaf can improve hematological parameters, has anti-inflammatory and anticholesterolemic properties (Obeagu et al., 2014).

Pretreatment is one of the unit operations in vegetable processing value chain. It is done primarily to aid the overall qualities of vegetables in terms of improvement/retention of nutritional, sensory and functional properties as well as reduction of microbial load. It is a modification unit operation and the extent of modification is governed by factors such as: method of pretreatment, duration of pretreatment and other properties(intrinsic/extrinsic) of the food to be pretreated. Neeto and Chen (2014) classified food pretreatment/processing methods into conventional and non-conventional. One

of the major characteristics of the conventional method is its dependency on high temperatures to achieve the objective of the pretreatment.

The non-conventional method of pretreatment which is sometimes referred to as novel or emerging pretreatment technology does not necessarily need high temperature. Some typical examples of non-conventional pretreatment method that are non-thermal are: Pulsed Electric Field (PEF), High Hydrostatic Pressure (HPP), irradiation, pulsed light (Neeto and Chen, 2014) and magnetic field. Non-conventional pretreatment method can also take place under sub-lethal or room temperature (Pereira and Vincente, 2010) that would not cause significant negative effects on product qualities. Also, assurance of food of better quality is high with non-thermal pretreatment (Barbosa-Canovas et al., 2005).

Blanching is a widely used method of pretreating fruits and vegetables. It is one of the conventional thermal (heat addition) processing methods of food. It involves dipping food materials in hot water (at 100 °C or slightly below) or other food grade liquids; holding it for a short time (few seconds to few minutes depending on the type and condition of the food); removal of the food from hot medium; and rapidly quenching the hot food with cold water to avoid cooking. Blanching can have negative effect on food nutrients such, as vitamins and phenolic compounds which are relatively unstable when subjected to heat treatments (Prochaska et al., 2000). The method has led to the degradation and leaching of nutritive components, such as sugars, minerals and vitamins of food during processing (Cumming et al., 1981; Rincon et al., 1993; Vidal-Valverde and Valverde 1993). Nobosse et al. (2017) reported that steam blanching caused reduction in vitamin C of moringa leaf. Higher blanching time and higher temperature negatively affected the vitamin C of three blanched leafy vegetables (Olayinka et al., 2012). Vitamin C (ascorbic acid) retention level was said to be the index for judging the overall nutrient retention ability of blanched food products (Murcia et al., 2000). The reason for this is that ascorbic acid (vitamin C) is the least stable nutrient during processing; it is highly sensitive to oxidation and leaching into water-soluble media during processing of food (Franke et al., 2004 in Patras et al., 2011).

Barbosa-Canovas et al. (2005) defined magnetic field as a region of space in which a magnetic body is capable of inducing surrounding bodies. Electromagnetism is the generation of magnetic field due to the flow of current in a conductor. In 1985, the use of magnetic field as a non-thermal method of preserving food was proposed for the first time (Barbosa-Canovas et al., 2005). When harvested vegetables are placed within magnetic field, the external magnetic field from either permanent or temporary magnetic (electromagnet) will interact with their living cells. This interaction will lead to modifications responsible for quality improvement. The guidelines given on the acceptable limit of exposure of different parts of human beings to magnetic field are 2-8T for head, trunk and limbs, and 400 mT for any part of the body (ICNIRP, 2009).

Magnetic field for food processing and related areas exist (Hayder et al., 2015, Ibara et al., 2015, Lipiec et al., 2004, Ordonez and Berrio 2011, Jia et al. 2015 and Kyle, 2015). However, available information is very few and sketchy on the use of magnetic field for vegetable processing and on nutritional qualities of pretreated foods. This is a clear indication that magnetic field is still grossly underutilized and its excellent advantages are yet to be substantially harnessed in food processing. Therefore, the objective of this study was to investigate the effect of three types of magnetic fields (generated by a developed electromagnetic field (EF) pretreatment device); magnetic field strength and pretreatment time on vitamin C, vitamin A and fibre of sweet peeper (SP) and fluted pumpkin leaf (FPL).

2. MATERIALS AND METHODS

2.1 Materials

An electromagnetic field pretreatment device; electronic weighing balance (OHAUS, Model 201, China), fresh samples of sweet pepper and fluted pumpkin leaf.

2.2 Experimental Procedures

Fresh samples of sweet pepper (SP) and fluted pumpkin leaf (FPL) of good quality were procured, sorted, washed and cut into pieces in order to ensure better exposure to the magnetic field pretreatment. After these, uniform experimental quantities per run (10 g for FPL and 100 g for SP) were measured with an electronic weighing balance (OHAUS, Model 201, China). The measured samples were placed in the electromagnetic field device. Selection of magnetic field types (Static, Pulse or Alternating)

with combination of magnetic field strength (5-30 mT) and pretreatment time (5-30 min) (set with timer on the device) was executed according to the experimental design and layout done with Design Expert software (version 6.0.6) as shown in Table 1.
Blanched and fresh samples were used as controls. After pretreatment, all samples were taken to the laboratory for analysis. AOAC (2005) standard procedure was used to analyze vitamin C, vitamin A and fibre content of all the samples.

Table 1. Experimental design and layout

SN	SMF/PMF/AMF				
	SP		FPL		
	MFS (mT)	PT (min)	MFS (mT)	PT (min)	Outputs
1	13.5 **(9.5)**	15 **(5)**	13.5 **(9.5)**	15 **(5)**	
2	19.0 **(5.0)**	20 **(25)**	19.0 **(5.0)**	20 **(25)**	
3	19.0 **(9.5)**	15 **(25)**	19.0 **(9.5)**	15 **(25)**	
4	19.0 **(9.5)**	15 **(15)**	19.0 **(9.5)**	15 **(15)**	
5	19.0 **(5.0)**	15 **(15)**	19.0 **(5.0)**	15 **(15)**	
6	8.0 **(9.5)**	25 **(15)**	8.0 **(9.5)**	25 **(15)**	
7	8.0 **(14.0)**	5 **(5)**	8.0 **(14.0)**	5 **(5)**	
8	19.0 **(9.5)**	15 **(15)**	19.0 **(9.5)**	15 **(15)**	
9	19.0 **(9.5)**	10 **(15)**	19.0 **(9.5)**	10 **(15)**	
10	24.5 **(14.0)**	15 **(15)**	24.5 **(14.0)**	15 **(15)**	
11	30.0 **(5.0)**	25 **(5)**	30.0 **(5.0)**	25 **(5)**	
12	30.0 **(9.5)**	5 **(15)**	30.0 **(9.5)**	5 **(15)**	
13	19.0 **(14.0)**	15 **(25)**	19.0 **(14.0)**	15 **(25)**	

SMF-Static Magnetic Field; **PMF**- Pulse Magnetic Field; **AMF**-Alternating Magnetic Field; **Outputs** are vitamin C, vitamin A and fibre content.
Note: *combination of values in brackets were used for AMF experiment and those not in brackets were used for SMF and PMF experiments.*

3. RESULTS AND DISCUSSION

3.1 Effect of Electromagnetic Field Pretreatment on the Vitamins C and A of SP and FPL

The illustrations of the effect of the electromagnetic field pretreatment on the vitamin C of SP and FPL are presented in Figures 1–4. For SP, all the electromagnetic field (EF) pretreatment combinations retained vitamin C (80 mg/100g) than blanched sample (about 70 mg/100g) with fresh sample having 74 mg/100g. Similarly, for FPL, almost all the EF pretreatments have vitamin C values higher than blanched (slightly above 60 mg/100g) and fresh samples (slightly above 60 mg/100g). The highest values of vitamin C (61.5 mg/100g) was obtained at PMF-7(24.5 mT and 15 min). Improvement/better retention of vitamin C under electromagnetic field pretreatment could be due to the absence or very mild presence of heat (Pereira and Vincente, 2010) during pretreatment. However, water blanching which is always associated with high pretreatment temperature (not less than 90^0C) caused vitamin C which is heat sensitive, water soluble and least stable during processing (Patras *et* al.,2011) to be depleted. Vitamin C of about 80 mg/100g and 120 mg/100g were obtained after pretreating onion and red bell pepper (sweet pepper) with osmotic solution of salt and drying at 60^0C (Alabi et al., 2016, and Odewole and Olaniyan, 2016). Blanching pretreatment also degraded the ascorbic acid (vitamin C) of *colocasia* vegetable by 43.12% - 63.19% (Kaushal et al.,2013).
Furthermore, almost all the electromagnetic field pretreatment caused the vitamin A content of SP to have between 0.0055 mg/100g to 0.008 mg/100g, but blanched and fresh samples have about 0.0055 mg/100 and 0.0078 mg/100g respectively. Similarly, for FPL, the vitamin A content was about 0.002 mg/100g – 0.003 mg/100g for most of the electromagnetic field pretreatment; fresh and blanched samples have about 0.002 and 0.001 mg/100g vitamin A respectively. These observations showed that electromagnetic field pretreatment (a non-thermal method) caused retention/improvement of vitamin A better than blanching pretreatment (a thermal method). Odewole and olaniyan (2016) obtained about

1.40 mg/100g vitamin A for red bell pepper (same as sweet pepper) pretreated with osmotic solution of salt and dried at 60^0C. Vitamin A content of mango chips pretreated with osmotic solution of sugar was found to be about 6.46 mg/100g (Odewole et al., 2014).

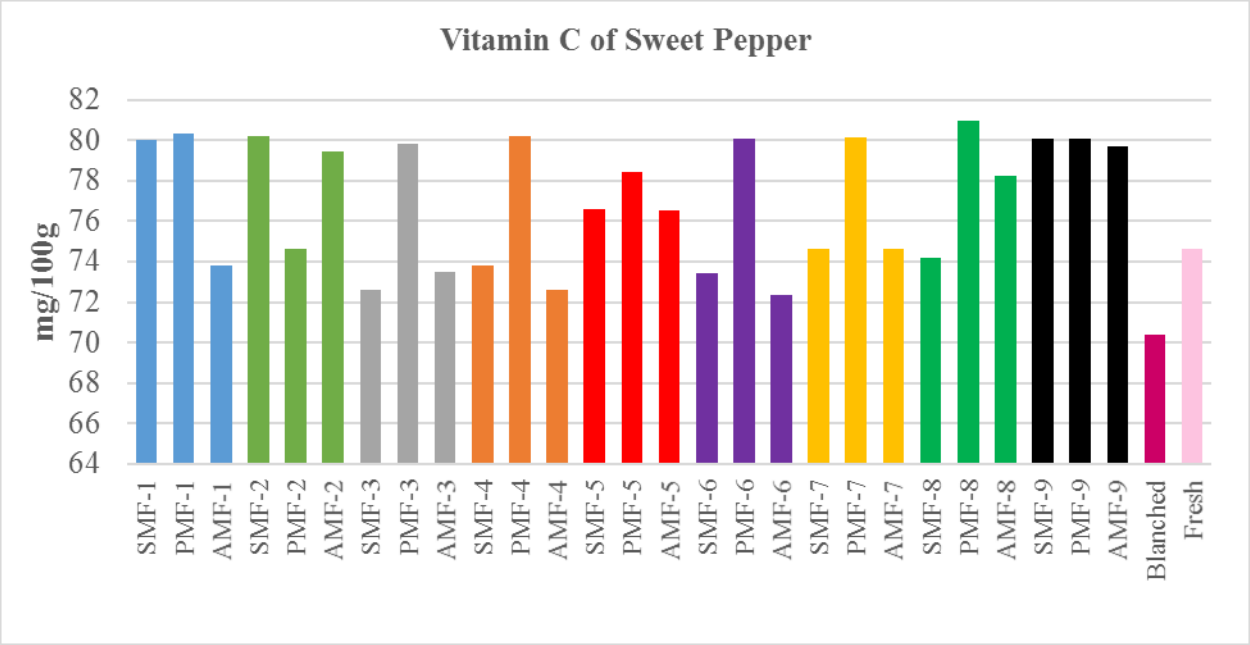

Figure 1. Effect of EF pretreatment on Vitamin C of sweet pepper

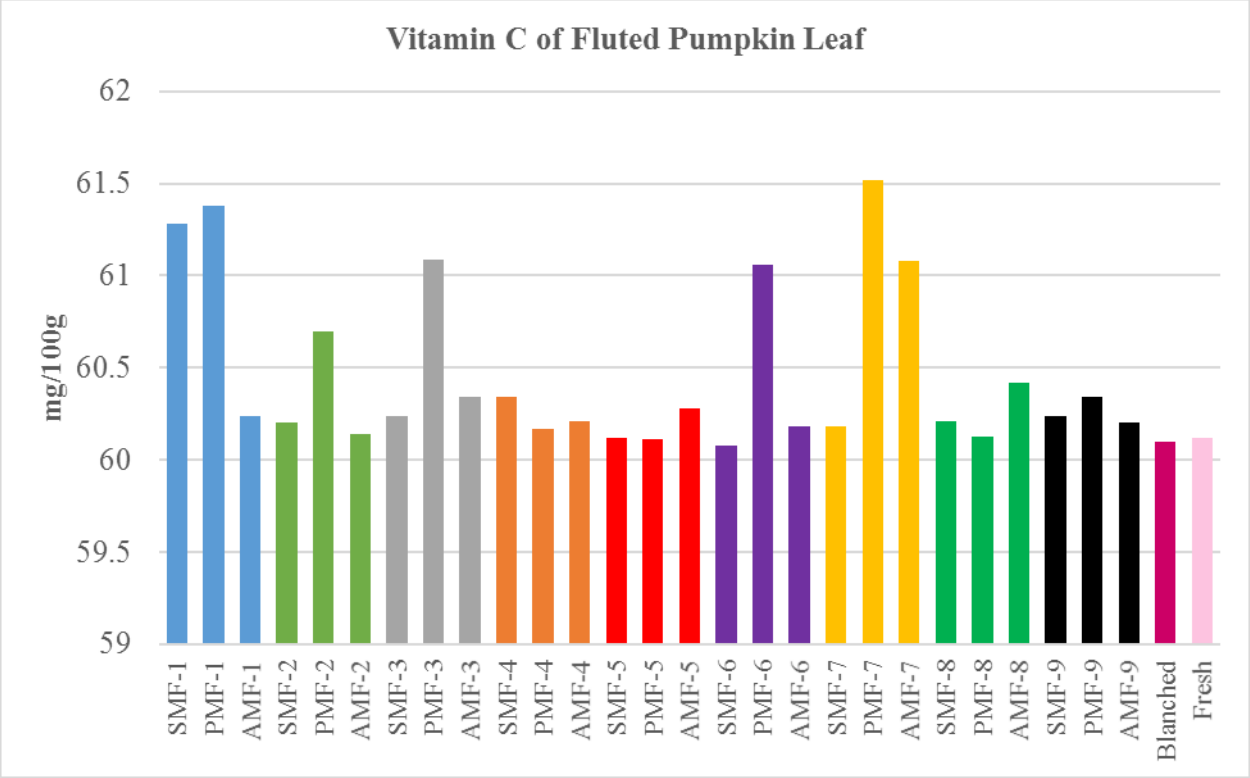

Figure 2. Effect of EF pretreatment on Vitamin C of fluted pumpkin leaf

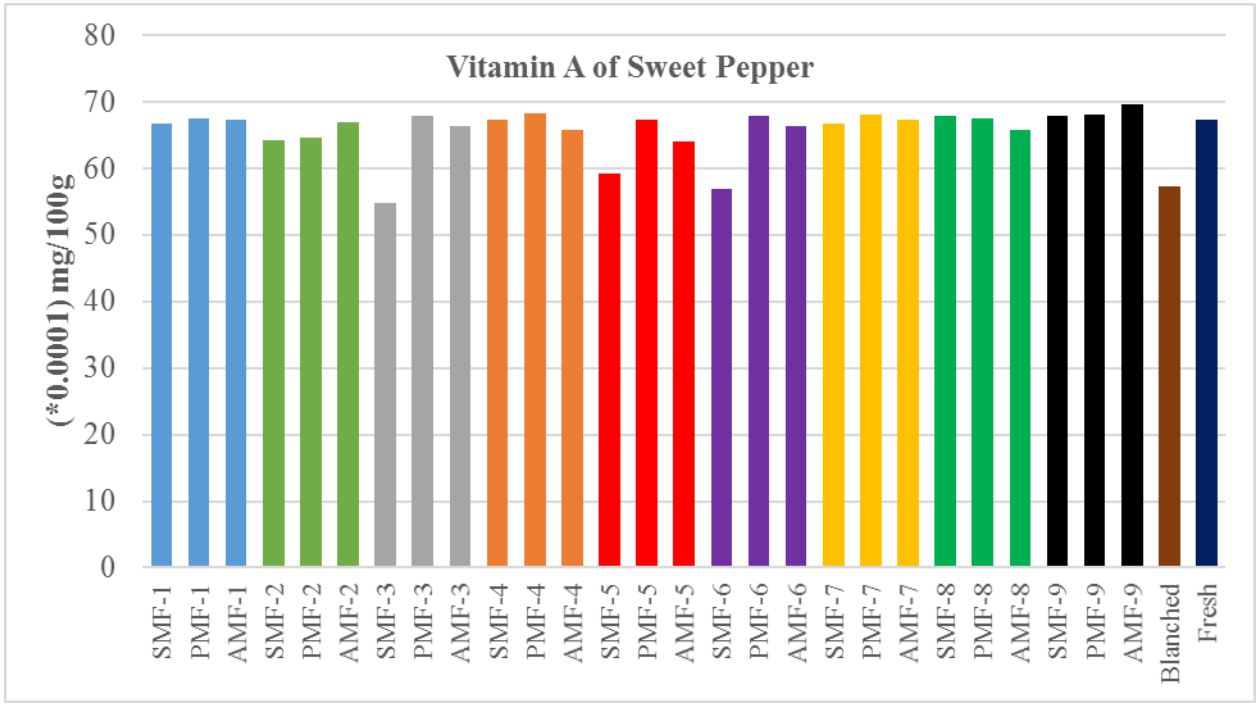

Figure 3. Effect of EF pretreatment on Vitamin A of sweet pepper

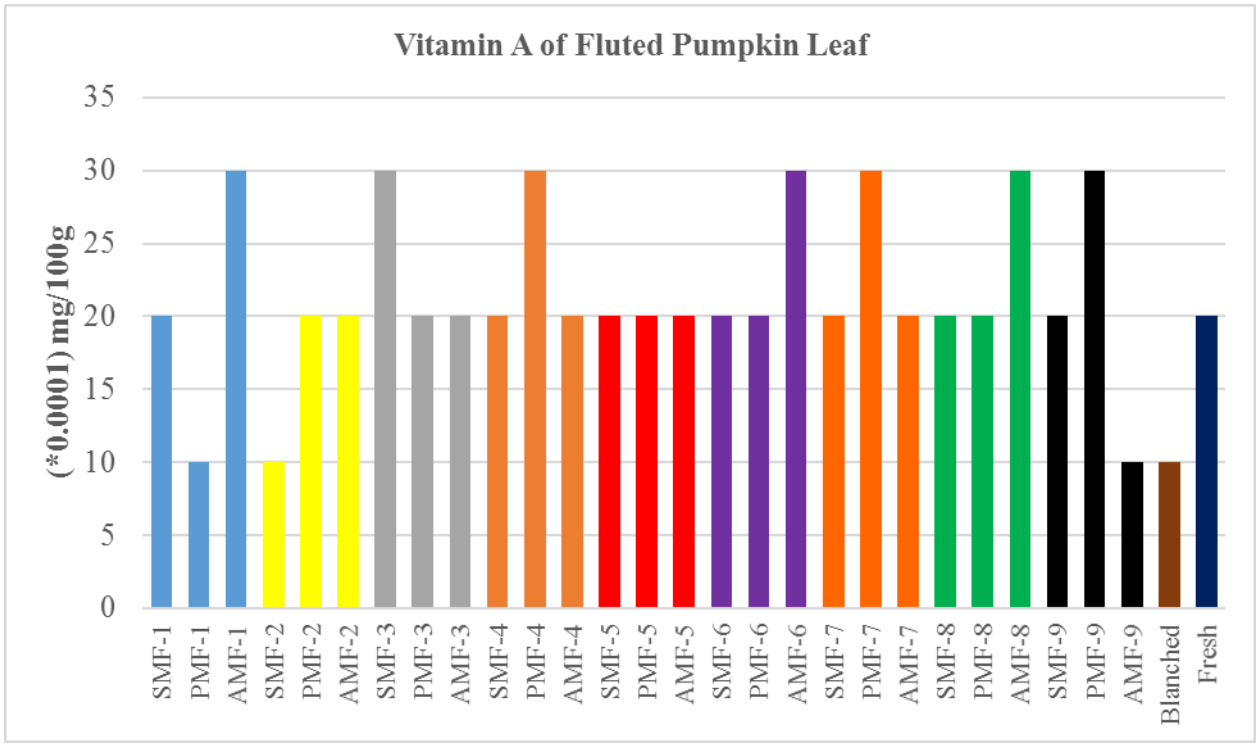

Figure 4. Effect of EF pretreatment on Vitamin A of fluted pumpkin leaf

3.2 Effect of Electromagnetic Field Pretreatment on the Fibre of SP and FPL

Figures 5 and 6 show the effect of electromagnetic field (EF) pretreatment on the fibre content of SP and FPL. Many EF pretreated and fresh samples of SP have fibre content more than the blanched sample. Highest value of about 2.6% of fibre was obtained for SP at SMF-3 (19 mT and 15 min), AMF-7(14 mT and 15 min) and SMF-8(19 mT and 15 min). For FPL, almost all the EF pretreated samples have fibre content higher than blanched and fresh samples. PMF-1 (13.5 mT and 15 min),

AMF-8 (5 mT and 5 min) and PMF-9 (30 mT and 5 min) have highest fibre value of 10% while blanched and fresh samples have about 7.5% and 7% respectively. The fibre content of sweet pepper was about 8% after pretreating with osmotic solution of salt and drying at 60^0C (Odewole and Olaniyan, 2015).

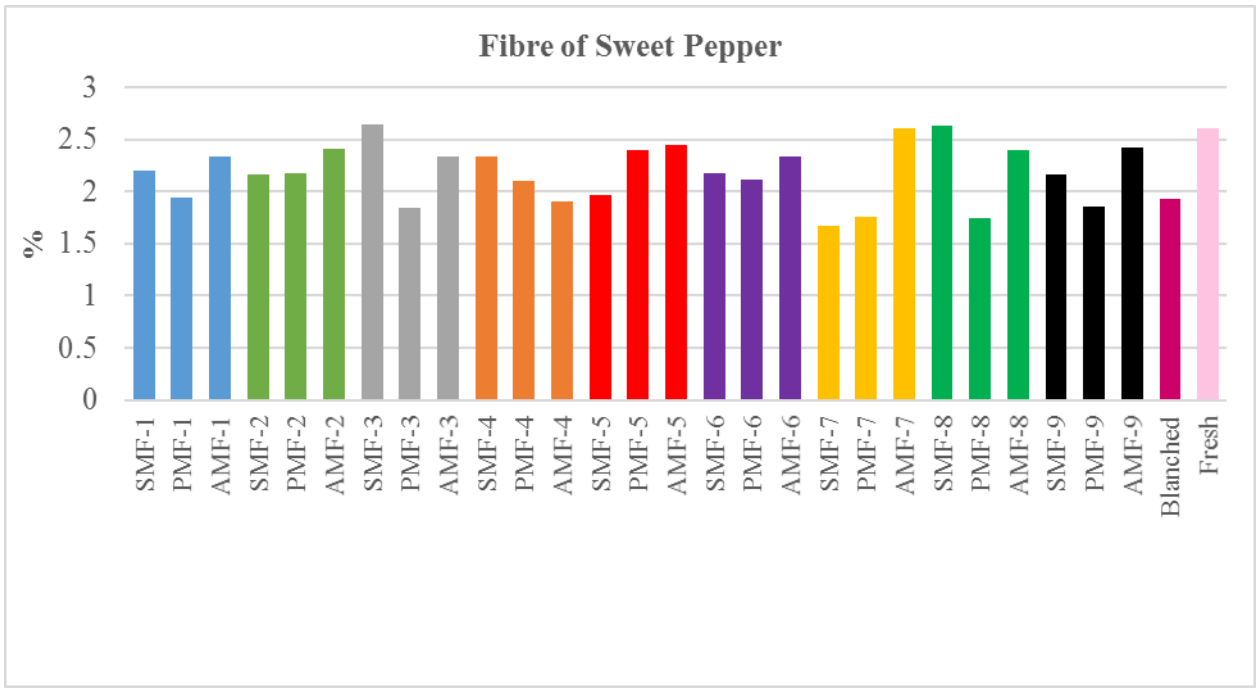

Figure 5. Effect of EF pretreatment on Fibre of sweet pepper

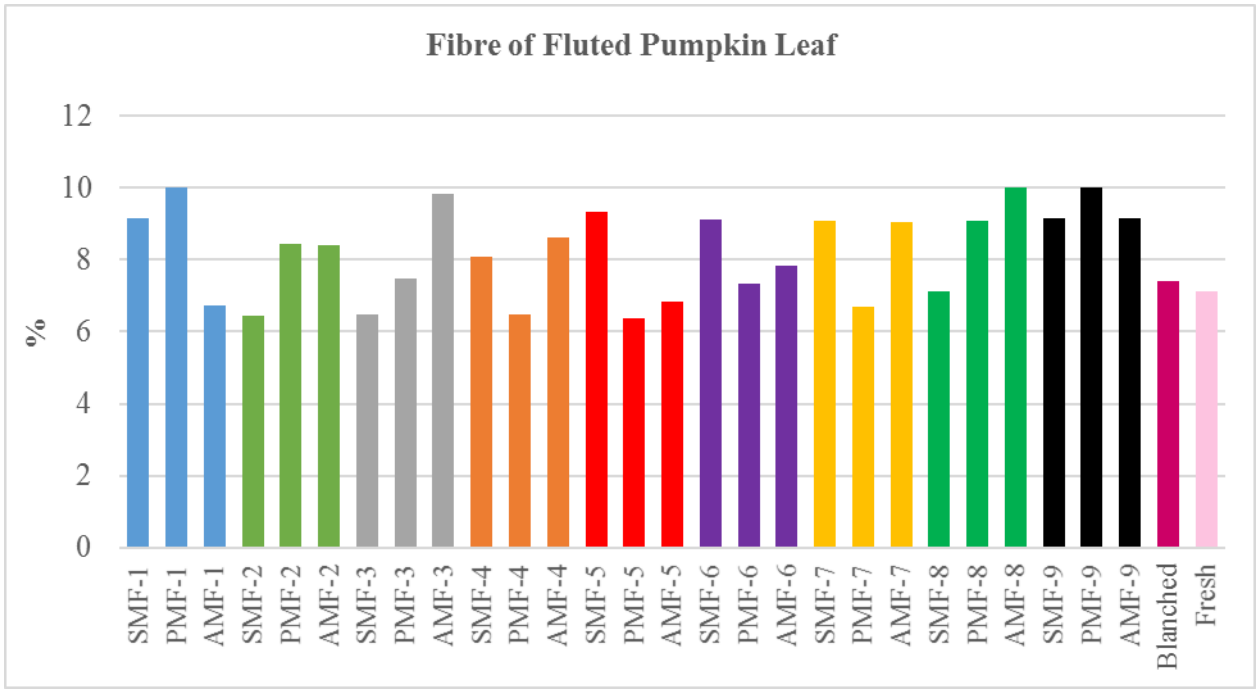

Figure 6. Effect of EF pretreatment on fibre of fluted pumpkin leaf

4. CONCLUSION AND RECOMMENDATION

Electromagnetic field pretreatment in most cases led to the improvement/better retention of vitamin C, vitamin A and fibre of sweet pepper and fluted pumpkin leaf than blanching. Therefore,

electromagnetic field pretreatment (a non-thermal method) is a promising pretreatment alternative that can be explored for replacing blanching (thermal method) in vegetable processing value chain. Modelling and optimization of the process is highly recommended for future research.

ACKNOWLEDGMENT

Authors specially acknowledge Dr. A. T. Ajiboye of the Department of Computer Engineering, University of Ilorin, Nigeria and Dr. S. A. Oyetunji of the Department of Electrical and Electronics Engineering, Federal University of Technology, Akure, Nigeria for their immense contributions to the development of the Electromagnetic Field Pretreatment Device used to conduct the experiment.

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Oral Session | Postharvest/Food Technology and Process Engineering
[4-1015-A] Postharvest/Food Technology and Process Engineering (1)
Wed. Sep 4, 2019 10:15 AM - 12:00 PM Hall A (Main Hall)

[4-1015-A-07] Pulsed electric fields applications in fresh meat

*Alaa El-Din Ahmed Bekhit[1] （1. University of otago(New Zealand)）
Keywords: meat, pulsed electric field, non-thermal, tenderness, quality

Pulsed electric fields (PEF) is a novel minimal processing technology that is applied to produce high quality food products with a natural flavour and fresh appearance and is gaining recognition due to the increasing demands of consumers for fresh and natural foods. The technology involves the application of an external electric field to induce electroporation, and formation of pores that increases the membrane and cellular permeability. Over the last 6 years, there has been much interest to use PEF to modify the properties of fresh meat. Our lab was the first to demonstrate the potential use of PEF in meat tenderization and achieved about 20% increase in tenderness of longissimus and semimembranosus beef muscles using various PEF processing intensities. This improvement in tenderness did not affect other major quality attributes such as colour and lipid oxidation. Further research from our lab demonstrated an early activation of Calpains, calcium activated proteases that are naturally found in the muscles and are involved in postmortem degradation of structural proteins. Recently, we used PEF to accelerate the dry aging of meat and demonstrated the ability to reduce the processing time to about half of its normal value. Further, the technology was also found to influence the diffusion, distribution and release of sodium from meat matrix and thus could be utilized as tool to reduce the sodium in processed meat products. This presentation will highlight the various potential applications of PEF in fresh meat and discuss the mechanisms responsible for the potential positive outcomes in PEF treated meat. Furthermore, negative aspects of PEF use will be also discussed with the aim of providing complete information on PEF application in fresh meat processing for proper evaluation of commercial use of the technology.

Pulsed electric field applications in fresh meat

Alaa El-Din A. Bekhit
Department of Food Science, University of Otago, Dunedin, New Zealand
aladin.bekhit@otago.ac.nz

ABSTRACT

Pulsed electric fields (PEF) is a novel minimal processing technology that is applied to produce high quality food products with a natural flavour and fresh appearance and is gaining recognition due to the increasing demands of consumers for fresh and natural foods. The technology involves the application of an external electric field to induce electroporation, and formation of pores that increases the membrane and cellular permeability. Over the last 6 years, there has been much interest to use PEF to modify the properties of fresh meat. Our lab was the first to demonstrate the potential use of PEF in meat tenderization and achieved about 20% increase in tenderness of longissimus and semimembranosus beef muscles using various PEF processing intensities. This improvement in tenderness did not affect other major quality attributes such as colour and lipid oxidation. Further research from our lab demonstrated an early activation of Calpains, calcium activated proteases that are naturally found in the muscles and are involved in postmortem degradation of structural proteins. Recently, we used PEF to accelerate the dry aging of meat and demonstrated the ability to reduce the processing time to about half of its normal value. Further, the technology was also found to influence the diffusion, distribution and release of sodium from meat matrix and thus could be utilized as tool to reduce the sodium in processed meat products. This presentation will highlight the various potential applications of PEF in fresh meat and discuss the mechanisms responsible for the potential positive outcomes in PEF treated meat. Furthermore, negative aspects of PEF use will be also discussed with the aim of providing complete information on PEF application in fresh meat processing for proper evaluation of commercial use of the technology.

Key words: meat, pulsed electric field, non-thermal, tenderness, quality.

Oral Session | Food Safety

[4-1015-C] Food Safety (1)

Chair:Anthony Mutukumira(Massey University, New Zealand), siti nurjanah(Bogor Agricultural University)
Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room C (3rd room)

[4-1015-C-01] Surface Pasteurisation of Fresh Chicken Meat using UV-C Technology

Arthur Jonathan Philip[1], Negah Nikanjam[1], Emilia Nowak[1], *Anthony Mutukumira[1] (1. Massey University(New Zealand))

10:15 AM - 10:30 AM

[4-1015-C-02] Efficient Filtering of Live *Escherichia coli* by Using 60 GHz CMOS Sensor

*Hiroki Fukuda[1], Tetsuhito Suzuki[1], Naoshi Kondo[1], Yuichi Ogawa[1] (1. Graduate School of Agriculture, Kyoto University(Japan))

10:30 AM - 10:45 AM

[4-1015-C-03] Safety Evaluation of Bacteriocinogenic Strains of *Pediococcus acidilactici* Isolated From Artisanal Cheeses

Luis Augusto Nero[1], Yosep Ji[2], Wilhelm Holzapfel[2], *Svetoslav Dimitrov Todorov[1] (1. Universidade Federal de Viçosa(Brazil), 2. Handong GLobal University(Korea))

10:45 AM - 11:00 AM

[4-1015-C-04] Sensitivity Comparison of Standard and real-time PCR Assay for Detection *Salmonella* Typhimurium and Enteritidis in Indonesian Chicken Carcasses

*siti nurjanah[1,2], Winiati Puji Rahayu[1,2], Ratih Dewanti-Hariyadi[1,2] (1. Department of Food Science &Technology, Bogor Agricultural University (IPB University)(Indonesia), 2. SEAFAST Center, Bogor Agricultural University (IPB University)(Indonesia))

11:00 AM - 11:15 AM

[4-1015-C-05] Development of Calculation Framework for Stochastic Prediction of Uncertainty and Variability in Survival Spore Numbers during Non-isothermal Inactivation by Second-order Monte Carlo Simulation

*Hiroki Abe[1], Kento Koyama[1], Kohei Takeoka[1], Shinya Doto[1], Shuso Kawamura[1], Shige Koseki[1] (1. Hokkaido University(Japan))

11:15 AM - 11:30 AM

[4-1015-C-06] Evaluation Growth Characteristics of Bacterial Spores Combine Treatment with High Hydrostatic Pressure and Alkaline Electrolyzed Water

*Koki Morita[1], Taiga Kuhara[1], Yoshinori Kamitani[1], Daisuke Hamanaka[1] (1. Kagoshima University faculty of agriculture(Japan))

11:30 AM - 11:45 AM

[4-1015-C-07] Impact of Mechanization Development on Women and Hired Labor Utilizations of Small-Scale Rice Farming Operations in Kampar Region, Indonesia

*UJANG PAMAN[1], Khairizal Kha, Hajry Arief Wahyudy (1. RIAU ISLAMIC UNIVERSITY(Indonesia))

11:45 AM - 12:00 PM

Oral Session | Food Safety
[4-1015-C] Food Safety (1)
Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room C (3rd room)

[4-1015-C-01] Surface Pasteurisation of Fresh Chicken Meat using UV-C Technology

Arthur Jonathan Philip[1], Negah Nikanjam[1], Emilia Nowak[1], *Anthony Mutukumira[1] (1. Massey University(New Zealand))

Keywords: Chicken, UV-C, Spoilage, Shelf-life

Fresh chicken meat is highly susceptible to surface contamination by spoilage and pathogenic microorganisms. The New Zealand safety standard stipulate that aerobic mesophilic counts (AMCs) present on surfaces of fresh chicken should be <7 log CFU.cm^{-2} by end of shelf-life when stored at 4˚C. The study investigated the effect of continuous ultraviolet light at 254 nm (UV-C) on the surface of fresh chicken samples. To determine the optimum UV-C parameter, fresh chicken portions (skinless breast fillet, skinless thigh fillet, skin-on breast fillet, and skin-on thigh fillet) were treated with four UV-C dosages (50, 100, 200, and 300 mJ·cm^{-2}) at ambient temperature (20˚C) using a commercial UV disinfection system. Temperature changes, exposure time and AMCs were determined as the responses. Standard enumeration of AMCs on fresh chicken portions was carried out by swabbing and plating dilutions on agar plate followed by 30˚C/72 h incubation. The result indicated that 50 mJ·cm^{-2} UV-C dose had maximum microbial reduction on surfaces of skinless and skin-on chicken samples with minimal temperature changes and lowest exposure times hence, it was selected as the optimum dosage for the two types of fresh chicken samples. The effect of 50 mJ.cm^{-2} UV-C dose was then investigated on the surfaces of fresh skinless and skin-on chicken breast samples. Treated samples intended for storage at 4˚C/7 days were repackaged. Instrumental color analysis, AMCs, lipid oxidation, and sensory evaluation were conducted during storage (4˚C) for 7 days. All the chicken samples were also tested for *E. coli*, *S. aureus*, *L. monocytogenes*, *Campylobacter* spp. and *Salmonella* spp. The fresh chicken samples were evaluated for appearance, odor, and texture by 5 semi-trained focus group panelists at 1, 5, and 7 days. Cooked chicken samples were evaluated by consumer sensory panelists (n=30) on days 1 and 7 using the 9-point hedonic rating scale. AMCs on control chicken samples exceeded the national standard on day 5 of storage, whereas UV-treated chicken samples ($p<0.05$) extended the shelf life to day 6 (skin-on) and day 7 (skinless) by reducing the initial cell counts and 3.80 ± 0.35 log CFU.cm^{-2} skinless chicken samples to 3.07 ± 0.34 and 1.87 ± 0.98 log CFU.cm^{-2}, respectively. Insignificant ($p>0.05$) differences of microbial counts between the control and UV-treated skin-on samples were found. Tests for the pathogens were negative in all the chicken samples. Although 50 mJ.cm^{-2} UV-C dose had no impact ($p>0.05$) on the color and lipid oxidation of both skin-on and skinless chicken samples, the sensory panelists detected a slight burnt odor of UV-C treated fresh raw chicken samples stored (4˚C) for day 1 which was not detected after cooking of the chicken samples that had been stored. The results suggested that 50 mJ.cm^{-2} continuous UV-C light (254 nm) chicken surface treatment successfully extended the shelf life by reducing the AMCs on skinless chicken portions compared to the skin-on samples.

Surface Pasteurisation of Fresh Chicken Meat using UV-C Technology

Arthur J. Philip, BEng; Negah. Nikanjam, MSc; Emilia Nowak, PhD; Anthony N. Mutukumira*, PhD

School of Food and Advanced Technology, Massey University, Auckland 0745, New Zealand

*Corresponding author: a.n.mutukumira@massey.ac.nz

ABSTRACT

Introduction

Fresh chicken meat is highly susceptible to surface contamination by spoilage and pathogenic microorganisms. The New Zealand safety standard stipulate that aerobic mesophilic counts (AMCs) present on surfaces of fresh chicken should be <6 log CFU cm^{-2} by end of shelf-life when stored at 4°C. The study investigated the effect of continuous ultraviolet light at 254 nm (UV-C) on the surface of fresh chicken samples.

Materials and Methods

To determine the optimum UV-C light dosage, fresh chicken portions (skinless breast fillet, skinless thigh fillet, skin-on breast fillet, and skin-on thigh fillet) were treated with four UV-C dosages (50, 100, 200, and 300 mJ cm^{-2}) at ambient temperature (20°C) using a commercial UV disinfection system. Temperature changes, exposure time and AMCs were determined as the responses. Standard enumeration of AMCs on fresh chicken portions was carried out by swabbing and plating dilutions on agar plate followed by 30°C/72 h incubation. The result indicated that 50 mJ cm^{-2} UV-C dose had maximum microbial reduction on surfaces of skinless and skin-on chicken samples with minimal temperature changes and lowest exposure times hence, it was selected as the optimum dosage for the two types of fresh chicken samples. The effect of 50 mJ cm^{-2} UV-C dose was then investigated on the surfaces of fresh skinless and skin-on chicken breast samples. Treated samples intended for storage at 4°C/7 days were repackaged. Instrumental color analysis, AMCs, lipid oxidation, and sensory evaluation were conducted during storage (4°C) for 7 days. All the chicken samples were also tested for *E. coli*, *S. aureus*, *L. monocytogenes*, *Campylobacter* spp. and *Salmonella* spp. The fresh chicken samples were evaluated for appearance, odor, and texture by 5 semi-trained focus group panelists at 1, 5, and 7 days. Cooked chicken samples were evaluated by consumer sensory panelists (n=90) on days 1 and 7 using the 9-point hedonic rating scale.

Results and Discussion

AMCs on control chicken samples exceeded the national standard on day 5 of storage, whereas UV-treated chicken samples ($p<0.05$) extended the shelf life to day 6 (skin-on) and day 7 (skinless) by reducing the initial cell counts of 3.31 ± 0.11 and 3.80 ± 0.35 log CFU.cm^{-2} to 3.07 ± 0.22 and 1.87 ± 0.98 log CFU cm^{-2} for skin-on and skinless chicken samples respectively. Insignificant ($p>0.05$) differences of microbial counts between the control and UV-treated skin-on samples were found, while significant differences ($p<0.05$) were found on the AMCs between control and UV-treated skinless chicken samples. Tests for the pathogens were negative in all the chicken samples. Although 50 mJ cm^{-2} UV-C dose had no impact ($p>0.05$) on the color and lipid oxidation of both skin-on and skinless chicken samples, the sensory panelists detected a slight burnt odor of UV-C treated fresh raw chicken samples stored (4°C) for day 1 which was not detected after cooking of the chicken samples that had been stored.

Conclusion and Recommendation

The results suggested that 50 mJ cm^{-2} continuous UV-C light (254 nm) chicken surface treatment successfully extended the shelf life by reducing the AMCs on skinless chicken portions compared to the skin-on samples.

Keywords: Chicken, UV-C, Spoilage, Shelf-life.

1. INTRODUCTION

Fresh chicken meat is an important source of protein worldwide. In 2018, the annual world poultry production reached 123 million tons (McLeod et al., 2018). In New Zealand, the consumption of chicken meat is about 40 kg per person (PIANZ, 2018). Fresh chicken meat is highly susceptible to surface contamination by spoilage and pathogenic microorganism due to their rich nutritional content and high-water activity. Microorganisms are already present on the skin of the birds and gastrointestinal tract before slaughter. Therefore, there is a high possibility for these microorganisms to spread and contaminate the fresh meat product through cross-contamination during handling and processing. Food contamination and spoilage by microorganism present serious problems for consumer safety. There have been numerous cases of food poisoning, pathogen outbreak, and product recalls worldwide (Bardon, Kolar, Cekanova, Hejnar, & Koukalova, 2009; Castaneda, 2017; Premarathne et al., 2017; Scheinberg, Doores, & Cutter, 2013). *Campylobacter jejuni*, *Salmonella* spp., *Listeria monocytogenes*, and *Escherichia coli* are the main pathogenic microorganism found on the surface of chicken meat (Castaneda, 2017; Cunningham, 2012; Premarathne et al., 2017; Scheinberg et al., 2013). These bacteria can infect human through consumption of cross-contaminated or undercooked chicken meat (Devleesschauwer, Bouwknegt, Mangen, & Havelaar, 2017; Pasquali et al., 2017; Premarathne et al., 2017).

The presence of spoilage bacteria on the surface of fresh poultry meat after processing is the main reason in determining the shelf-life of the product (Octavian & Octavian, 2010; Petracci & Fletcher, 2002; Russell, Fletcher, & Cox, 1995). The growth of the spoilage microorganisms during cold-storage can lead to quality defects such as discoloration, development of off-odor, and development of off-flavor (James, 2005; Mead, 2004; Pearson & Dutson, 1994; Shall, 2013). Once the growth of the spoilage microorganisms reaches high numbers ($>10^5$ CFU cm^{-2}), they can produce metabolites that cause the defects to become more noticeable. The shelf-life of fresh poultry meat products ultimately end when the consumer is able to notice and identify these defects (Carvalho, Shimokomaki, & Estévez, 2017; Parrott & Walley, 2017). Therefore, international food safety authorities such as USFDA and FSANZ recommended that AMCs present on the surface of fresh chicken meat should be $<10^6$ CFU cm^{-2} at the end of shelf-life (FSANZ, 1995; Hasell & Salter, 2003).

Different food preservation methods have been developed and applied in food processing to control or reduce contamination thereby extending the shelf-life of food products. Heat and chemical treatment are the most common methods of microorganism inactivation (Huang, Wu, Lu, Shyu, & Wang, 2017; Tewari & Juneja, 2007). Despite being highly effective, heat treatment and chemical antimicrobial agent often destroy sensory properties and valuable nutrients such as protein and vitamins (Koutchma, 2008, 2009; Tewari & Juneja, 2007).

Alternative non-thermal and non-chemical preservation methods have been investigated for food processing application. Ultraviolet (UV) light technology, high pressure processing (HPP), high voltage processing, and gamma irradiation, are some of the examples of alternative preservation methods (Gould, 2001; Gunter-Ward et al., 2018; Lynch, 2016; Seemeen, 2011; Tewari & Juneja, 2007). UV light technology in particular, is a non-ionizing irradiation spectrum of light that possess germicidal capabilities (Ahmad, Christensen, & Baron, 2017; Gabriel, Ballesteros, Rosario, Tumlos, & Ramos, 2018; Gunter-Ward et al., 2018; Koutchma, 2008, 2009; Unluturk & Atilgan, 2014). UV light has several advantages over other alternative technologies including ease of operation and cost efficiency (Baysal, Molva, & Unluturk, 2013; Gunter-Ward et al., 2018).

The USFDA and European Food Safety Authority (EFSA) have recently approved the application of UV-C light (240-315 nm) for the treatment of various types of food such as bread, juice and dairy products (Forney & Moraru, 2009). UV-C was first applied as a substitute for heat treatment for the pasteurisation of liquid food products such as fruit juice and milk (Ahmad et al., 2017; Gabriel et al., 2018; Gunter-Ward et al., 2018). Successful applications of UV-C have also been reported for surface pasteurisation of fruit, vegetables, raw meat, and cooked meat (Baysal et al., 2013; Butot et al., 2018; Gamage, 2015; Heinrich, Zunabovic, Varzakas, Bergmair, & Kneifel, 2016; Semi, 2016)

UV-C light technology has a huge potential for poultry processing application. The germicidal capabilities paired with minimal impact on sensory properties of the meat product make UV-C technology a suitable processing aid in the poultry industry. UV-C light processing can reduce the presence of spoilage bacteria on the surface of fresh chicken product directly after processing, resulting in the extension of shelf-life. Increasing the shelf life of fresh chicken meat product will lead to the increase in food safety, economic value, as well as decrease food waste. Despite the advantages of UV-C application in the food industry, application of the technology has been generally been slow worldwide, including in New Zealand (Koutchma, 2008, 2009). Therefore, the aim of this study was to investigate the potential of UV-C light processing for surface pasteurisation of fresh chicken meat portion.

2. MATERIALS AND METHODS

2.1 Samples

Skinless breast fillet (SLBF), skin-on breast fillet (SOBF), skinless thigh fillet (SOTF), and skin-on thigh fillet (SOT) chicken samples were supplied by a local commercial poultry processing factory in Auckland, New Zealand. The chicken portions were packed in bulk (5 kg) and delivered to the Microbiology Laboratory under chilled conditions (4°C) within one hour.

2.2. UV-C Light Surface Pasteurisation Optimisation

The goal of the optimisation was to select an optimum UV-C dosage for surface pasteurisation with maximum bacterial reduction of viable cell counts, minimum temperature increase, and lowest exposure duration. A factorial experiment consisting of 2 factors (UV-C light dosages and chicken meat type) with 4 levels was generated to determine the optimum dosage for continuous UV-C light surface pasteurisation process on fresh chicken meat portions.

2.3. UV-C light Surface Pasteurisation Treatment

The UV-C light surface pasteurisation was conducted using the Joulesafe® UV disinfection system (Radiant UV, USA). Twelve (12) low-pressure mercury lamps, each emitting 254 nm UV light were the sources of the UV-C light. The mercury lamps were mounted at the top and bottom of the UV-C chamber, providing complete coverage of UV light exposure. The equipment also recorded the intensity and exposure duration of each cycles of UV-C light exposure process. The UV-C light surface pasteurisation dosage was automatically adjusted by the equipment. The fresh chicken samples were treated with four different UV-C dosages: 50, 100, 200, and 300 mJ cm^{-2} at ambient temperature (20°C). The samples were placed on a custom-made tray provided by the manufacturer and placed inside the equipment for UV-C light exposure process. Following UV-C light exposure, the chicken samples were individually packed using polyethylene terephthalate (PET) tray with a polyethylene sealant layer and stored for 7 days at refrigeration temperature (4°C).

The temperature on the surface of the chicken samples was measured using an RS PRO RS-41 thermometer (RS Components Ltd., UK) equipped with a 20-cm probe before and after UV-C treatment. Temperature measurement were conducted in triplicates.

2.4. Microbiological analysis

Wet and dry swab sampling procedure of ISO 18593 was used to collect swab samples (Castaneda, 2017). Following UV-C light surface pasteurisation, the surface of each sample was swabbed with three sterile cotton swabs (Nanjing Luster Medical & Healthcare Products, China) and a 5-cm^2 sterile template (Fort Richard, NZ). Firstly, the first swab was pre-moistened using maximum recovery diluent (MRD) (Oxoid, NZ) at 0.1% (w/w). The pre-moistened swabs were used to swab the surface of the chicken samples for 30 seconds. The tips of the swabs were aseptically broken and placed into 10-ml sterile peptone water. The second and third swabs were used to swab the same surface to ensure maximum recovery of bacteria from the surface of the sample. The glass bottle containing the swab samples and MRD were mixed thoroughly using a vortex mixer (VM-96B JEIO TECH, Korea). Serial dilutions of the samples were prepared up to 10^{-6} dilution. Each dilution was aseptically transferred (0.1 mL) to the surface of suitable medium (solidified agar) for each respective bacterial species (except for *Escherichia coli)*. Agar plates for aerobic mesophilic counts (AMC) were incubated at

30°C/ 72 h; *Salmonella* spp., *Staphylococcus aureus,* and *Listeria Monocytogenes* were incubated at 35°C/24 h. For *Campylobacter* spp., the mCCDA plates were stacked inside an airtight rectangular plastic container (Castaneda, 2017). Two CampyGen™ (ThermoFischer Scientific, USA) sachets were placed inside the container to create microaerophilic conditions (84% N_2, 10% CO_2, and 6% O_2). The plates were then incubated at 42°C for 48 h. Developed colonies were counted after incubation and expressed as $\log_{10}$ CFU cm^{-2}.

The enumeration of *Escherichia coli* was carried out using the pour plate method. VRB agar was prepared following the manufacturer's instruction on the day of experiment and was kept at 48°C (Castaneda, 2017; Chun, Kim, Lee, Yu, & Song, 2010). One ml of each dilution was pour plated on the VRB agar. The solidified plates were incubated at 35°C/24 h. After incubation, developed colonies were enumerated as previously described.

2.5. Effect of UV-C Light Surface Pasteurisation during Storage

Following optimisation, one optimum UV-C light dosage was selected. The effect of the optimum dosage on the psychochemical and sensory quality of fresh chicken meat portions during refrigerated storage (4°C) was analysed by conducting microbial enumeration, color measurement, lipid oxidation analysis, and sensory evaluation on UV-C treated and untreated fresh chicken samples (SLBF and SOBF) during 7-day storage under refrigerated conditions (4°C). Microbial enumeration was conducted as described in the previous sub-chapter at day 0, 3, 5, and 7 of storage.

2.5. Lipid Oxidation Analysis and Instrumental Color Measurement

The degree of lipid oxidation of the untreated and UV-C treated fresh chicken samples was measured using the TBA method described by Chun et al. (2010) and Ahn et al. (1998). Five grams of sample were homogenized using a blender (BFP 100, Breville Inc, Australia) in 15 mL distilled water. One mL of each meat (sample) homogenate and 2 mL of 20 mM 2-thiobarbituric acid/15% trichloroacetic acid (TBA/TCA) solution were transferred into a test tube. The mixture was mixed using a vortex mixer (VM-96B JEIO TECH, Korea) and incubated in boiling water for 15 minutes to develop color. The mixture allowed to cool to room temperature (20°C) and then centrifuged (6-16KS, Sigma, Germany) at 2000 *g* for 15 minutes. The absorbance of the resulting supernatant was measured using a spectrophotometer (UV-1601, Shimadzu, Japan) at 531 nm. Thiobarbituric acid reactive substances (TBARS) values represented the degree of lipid oxidation and were calculated using the malonaldehyde standard curve prepared using 1,1,3,3-tetra-ethoxypropane (TEP). The TBARS values were expressed as milligrams malonaldehyde in one kilogram of meat sample (MDA/kg). The lipid oxidation measurement was conducted in three replicates.

A Minolta CR-300 Colorimeter (Minolta Company, Tokyo, Japan) equipped with illuminant D65 as the light source was used to measure the color of the samples (Chun et al., 2010; Seemeen, 2011). The measuring head of the CR-300 used diffuse illumination/0° viewing geometry to measure the color of the samples as viewed under diffuse lighting conditions. The colorimeter was calibrated using a standard white calibration plate provided by the manufacturer with L* value of 94.01, a* value of 0.29, and b* value of 1.77. The color measurements were conducted in five replicates. The Hunter's color values (L*, a*, b*) and lipid oxidation of the samples were measured and recorded on days 0, 3, 5, and 7 during storage.

2.7. Sensory Evaluation

The sensory evaluations of untreated and UV-treated chicken meat samples were conducted by a focus group and consumer sensory participants who used the 9-point hedonic scale (McLeod et al., 2018; Seemeen, 2011). A focus group comprising of five panelists evaluated the raw chicken samples during storage for seven days. Four samples (untreated skin-on chicken breast, UV treated skin-on chicken breast, untreated skinless chicken breast, and UV treated skinless chicken breast) were presented to the focus group panelists. The panelists evaluated the samples for appearance, texture and odor. Ninety (90) consumer sensory evaluation participants evaluated the cooked samples (cooked untreated and UV-C treated chicken) using the 9-point hedonic scale at days 1 and 7 of storage (McLeod et al., 2018; Seemeen, 2011). The chicken samples were roasted in a convection oven (Bakbar Turbofan 32 Max,

Moffat, Australia) without any seasoning to a center temperature of 75°C. Internal temperature of the samples during cooking process was monitored using a temperature probe (Part number – 16002, Sensing Devices Limited, UK) connected to a probe log. The cooked products were cooled to 30 – 40°C and then cut into uniform portions (2 x 2 cm) for sensory evaluation. Four different cooked chicken samples (untreated skinless breast, UV-treated skinless breast, untreated skin-on breast, and UV-treated skin-on breast) were evaluated by sensory panelists. The samples from each treatment were coded with random three-digit numbers before being presented to the sensory panelists. Sensory panelists were provided with crackers and still bottled water to rinse their palates during sensory evaluation. The consumer sensory panelists evaluated the test samples for taste, texture, flavor, freshness and the overall acceptability of the sample on a 9-point hedonic scale.

2.8. Statistical Analysis

The data obtained in this study were analysed using Minitab Statistical Software version 17.0 (Minitab Inc., USA, 2009). Data on optimisation/selection of UV-C light surface pasteurisation dosage was analysed using the general linear model. Microbial cell counts, TBARS, Hunter L*, a*, b* values, and sensory evaluation data obtained during storage were analysed using one-way analysis of variance (ANOVA) and significant means were separated by Tukey's post-hoc test.

3. RESULTS AND DISCUSSION

3.1 Selection of Optimum UV-C Light Surface Pasteurisation Dosage

The goal of the optimisation of UV-C light surface pasteurisation was to select a dosage capable of maximum reduction of AMCs with minimum temperature increase and exposure duration. The AMCs reduction of UV-C light dosages at 50 to 300 mJ cm^{-2} ranged from 1.69 to 2.98 log CFU cm^{-2} and 0.21 to 0.86 log CFU cm^{-2} for skinless and skin-on samples, respectively. The result indicated that increasing UV-C light dosages from 50 to 300 mJ cm^{-2} had no significant effect on the microbial reduction ($p>0.05$). The results also suggested that the reduction of AMCs was more effective ($p<0.05$) on the surface microflora of skinless chicken meat samples compared to their skin-on counterparts, which is in agreement with studies conducted by Isohanni and Lyhs (2009) and Haughton et al. (2011). UV-C light treatment on the surface of fresh chicken meat portions using dosages of 50 – 200 mJ cm^{-2} reduced AMCs from 1.41 to 1.76 log CFU cm^{-2} and 0.05 to 0.14 log CFU cm^{-2} for skinless and skin-on chicken breast fillet respectively (Haughton et al., 2011; Isohanni & Lyhs, 2009). The previous studies also concluded that increasing the UV-C light dosage from 50 up to 200 mJ cm^{-2} did not increase microbial reduction on both skinless and skin-on chicken meat samples ($p<0.05$).

Absorption of UV-C light by the DNA causes mutation in the microorganisms leading to cell death (Gabriel et al., 2018; Heinrich et al., 2016; Koutchma, 2008). As the method relies on direct exposure of light on the microorganisms residing on the surface, factors such as surface topography, UV-C light dosage and equipment, affect the inactivation efficiency (Chun et al., 2010; Gayán, Álvarez, & Condón, 2013; Heinrich et al., 2016). The surface of chicken skin is highly irregular in texture, which shelters microorganism from UV-C light (Haughton et al., 2011; Petracci & Fletcher, 2002). The surface topography of chicken meat is smoother than the skin, therefore the UV-C light treatment is more effective on skinless chicken meat surfaces.

The result also suggested that temperature increase and exposure duration were mainly influenced by the UV-C light dosage. Temperature increased from 2.43 to 15.77°C and 2.93 to 12.83°C for skinless and skin-on chicken samples respectively, when treated with UV-C dosage of 50 to 300 mJ cm^{-2}. There was no difference ($p<0.05$) between the temperature increases on skinless and skin-on chicken samples treated with the same UV-C light dosages. The duration of UV exposure ranged from 2.16 to 12.58 minutes (skinless) and, 2.16 to 13.03 minutes (skin-on) for samples treated with 50 to 300 mJ cm^{-2}. No significant differences between the exposure duration on skinless and skin-on chicken samples treated with the same UV-C light dosage ($p<0.05$). Prolonged UV-C exposure on the surface of chicken product can generate heat which may accelerate lipid oxidation, produce off-flavors and off-odors (Chun et al., 2010; Haughton et al., 2011; McLeod et al., 2018; Park & Ha, 2015). Therefore, it is important to select optimum UV-C dosages with low exposure times to minimize the increase in

temperature during the surface pasteurisation process. In this study, the UV-C light dosage of 50 mJ cm^{-2} was selected as the optimum dosage since it possesses bacterial reduction capabilities that is not significantly different ($p>0.05$) compared to other dosages (100, 200, and 300 mJ cm^{-2}) while demonstrating the lowest exposure duration and minimal temperature increase.

3.2 Effect of Optimum UV-C Light Dosage on the Growth of Bacteria

The effect of selected (optimum) UV-C light surface pasteurisation dosage (50 mJ cm^{-2}) on the growth of microorganism (AMCs) during refrigerated storage (4°C) is shown in Figure 1. The initial AMCs present on the surface of the fresh chicken meat were 3.31 ± 0.11 and 3.80 ± 0.35 log CFU cm^{-2} for skin-on and skinless chicken meat samples, respectively. The initial AMCs were reduced to 3.07 ± 0.22 and 1.87 ± 0.98 log CFU cm^{-2} giving microbial log reduction value of 0.24 and 1.93, respectively. Thus, the microbial reduction on skin-on chicken breast fillet samples after UV exposure was insignificant ($p>0.05$), whereas significant AMCs reduction were observed on skinless chicken breast fillet ($p<0.05$). During storage trials, the two types of products (skin-on and skinless breast fillet) treated with UV-C light showed delayed AMCs growth compared to untreated (control) samples and the effectiveness was more pronounced towards the end of storage time. After the initial reductions, the differences in the microbial counts were stable ($p<0.05$) during storage. The AMCs for untreated skinless chicken breast surpassed the recommended limit set by FSANZ (1995) after day 5 of storage, while the AMCs for UV-C treated skinless breast surpassed the limit after day 7 of storage (Figure 1A). The AMCs for untreated skin-on chicken breast surpassed the limit day 5 of storage, while the AMCs for UV-treated skin-on chicken breast was higher than the limit on day 6 of storage (Figure 1B).

There are limited studies on the effectiveness of UV-C treatment on the growth of pathogens on the surface fresh chicken meat during refrigerated storage (4°C). Chun et al. (2010) showed the effectiveness of 50 mJ cm^{-2} UV-C light on growth of surrogate pathogens (*C. jejuni, L. monocytogenes, Salmonella* Typhimurium) on skinless chicken breast fillet during storage for 6 days at 4°C. In the present study, *Campylobacter* spp., *Salmonella* spp., *E. coli, S. aureus,* and *L. monocytogenes* were not detected in any of the samples which indicated effectiveness of the immersion chilling step in the commercial poultry processing factory (Demirok et al., 2013; James, Vincent, de Andrade Lima, & James, 2006; Zhang, Jeong, Janardhanan, Ryser, & Kang, 2011).

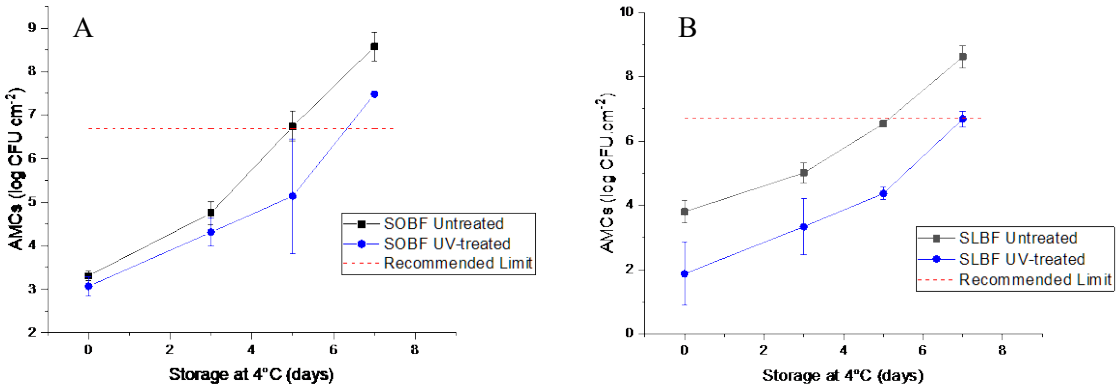

Figure 1. Aerobic mesophilic counts (AMCs) of untreated and UV-C treated (50 mJ cm^{-2}) fresh chicken meat samples.

Notes: SLBF = Skinless Breast Fillet (A); SOBF = Skin-on Breast Fillet (B); Dashed horizontal line = FSANZ (1995) microbiological criteria for foods recommended AMCs ($<5 \times 10^6$ CFU cm^{-2}) on fresh chicken meat product at the end of shelf-life. Error bars represent the standard deviation of the mean values; experiment was conducted in 2 replicates with 3 determinations each.

3.3 Color and Lipid Oxidation

Lipid oxidation and color are two of the most important non-microbial physicochemical attributes of fresh chicken meat product (Carvalho, Shimokomaki, & Estévez, 2017). It was therefore important to evaluate impact of UV-C light processing on the two physicochemical parameters on fresh chicken meat samples during refrigerated storage (4°C). The degree of lipid oxidation (shown as TBARS values) is shown in Table 1. The changes of the TBARS in both UV-treated and untreated skin-on and skinless chicken breast were not significant ($p>0.05$). The difference of TBARS value between UV treated and untreated sample as well as the changes of TBARS value throughout the storage period was not significant ($p>0.05$).

Table 1. TBARS (MDA/kg) * of chicken breast fillet samples during storage at 4°C.

Sample Type	Storage (day)	Untreated (Control)	UV-C Light Treated (50 mJ cm^{-2})
Skin-on breast fillet	0	$^{a}1.72 \pm 0.56^{a}$	$^{a}3.09 \pm 0.70^{a}$
	3	$^{a}1.24 \pm 0.36^{a}$	$^{a}2.14 \pm 1.38^{a}$
	5	$^{a}1.40 \pm 0.08^{a}$	$^{a}2.22 \pm 0.27^{a}$
	7	$^{a}3.23 \pm 1.39^{a}$	$^{a}2.46 \pm 0.83^{a}$
Skinless breast fillet	0	$^{a}2.11 \pm 0.75^{a}$	$^{a}1.34 \pm 0.89^{a}$
	3	$^{b}0.58 \pm 0.14^{a}$	$^{a}0.22 \pm 0.21^{a}$
	5	$^{ab}1.03 \pm 0.06^{a}$	$^{a}1.61 \pm 0.64^{a}$
	7	$^{a}2.14 \pm 0.35^{a}$	$^{a}1.43 \pm 0.65^{a}$

Notes: Means* of TBARS followed by standard deviation (±). Within columns of each sample type, different superscripts in front of mean values indicate significance ($p<0.05$). Within rows of each sample type, mean values followed by different superscript letters are significantly different ($p<0.05$); MDA = Malonaldehyde. Experiment was conducted in two replicates with three determinations each.

The color measurement results indicated that UV-C light treatment had a significant effect ($p<0.05$) on the Hunter L*, a*, and b* values of skin-on chicken breast fillet during storage (Table 2). UV-C light treatment had a slight effect on the b* values and no effect ($p>0.05$) on the Hunter L* and a* values of skinless chicken breast fillet during storage. The slight changes of b* values have been previously reported (Chun et al., 2010; Park & Ha, 2015). Overall, UV-C light treatment had more impact on the physicochemical attributes of skin-on chicken samples compared to skinless chicken samples. Published data reported that UV-C light treatment have no significant effect on the physicochemical attributes of skinless chicken meat during storage. Chun et al. (2010), Park and Ha (2015), and McLeod et al. (2018) all reported that UV-C light treatment at 50 mJ cm^{-2} have no significant effect on the rate of lipid oxidation and color of skinless chicken breast fillet.

Table 2. Hunter L*, a*, and b* values* of chicken breast fillet samples during storage at 4°C.

Sample Type	Hunter values	UV-C dosage	Storage period (day)			
			0	3	5	7
Skin-on breast fillet	L*	Control	60.81 ± 0.33^{a}	56.80 ± 0.01^{d}	57.66 ± 0.01^{c}	57.66 ± 0.01^{c}
		50 mJ cm^{-2}	60.68 ± 0.04^{a}	58.61 ± 0.01^{b}	56.34 ± 0.02^{e}	56.34 ± 0.02^{e}
	a*	Control	-1.12 ± 0.01^{a}	-1.05 ± 0.01^{b}	-0.96 ± 0.01^{c}	-0.53 ± 0.01^{f}
		50 mJ cm^{-2}	-1.06 ± 0.01^{b}	-0.96 ± 0.01^{c}	-0.86 ± 0.01^{d}	-0.58 ± 0.01^{e}
	b*	Control	0.97 ± 0.01^{e}	0.78 ± 0.03^{f}	0.63 ± 0.02^{g}	0.41 ± 0.02^{h}
		50 mJ cm^{-2}	1.78 ± 0.05^{a}	1.58 ± 0.02^{b}	1.44 ± 0.02^{c}	1.16 ± 0.01^{d}
Skinless breast fillet	L*	Control	42.37 ± 0.09^{a}	41.35 ± 0.13^{b}	40.78 ± 0.37^{c}	40.24 ± 0.01^{d}
		50 mJ cm^{-2}	42.39 ± 0.01^{a}	41.21 ± 0.01^{b}	40.63 ± 0.03^{c}	40.24 ± 0.01^{d}
	a*	Control	1.14 ± 0.02^{a}	1.09 ± 0.01^{b}	0.74 ± 0.01^{c}	0.61 ± 0.03^{d}
		50 mJ cm^{-2}	1.16 ± 0.01^{a}	1.08 ± 0.01^{b}	0.73 ± 0.01^{c}	0.62 ± 0.01^{d}
	b*	Control	1.30 ± 0.02^{a}	0.83 ± 0.03^{c}	0.63 ± 0.04^{d}	0.41 ± 0.01^{e}
		50 mJ cm^{-2}	0.92 ± 0.03^{b}	0.83 ± 0.01^{c}	0.59 ± 0.02^{d}	0.46 ± 0.02^{e}

Notes: Means* of Hunter L*, a*, and b* values followed by standard deviation (±). L*, degree of lightness (0 – 100 = black – white); a*, degree of redness ((-80) – (+100) = green – red); b*, degree of yellowness ((-80) – (+70) = blue – yellow). Within columns and rows of each sample type and color values (L*, a*, and b*), mean values followed by different superscript are significantly different ($p<0.05$). Experiment was conducted in two replicates with five determinations each.

3.4 Sensory Evaluation

Raw untreated and UV-C light treated (50 mJ cm^{-2}) skinless and skin-on chicken breast samples were evaluated for appearance, odor, and texture by a focus group on day 1, 5, and 7 of storage. The focus group found no difference in the appearance and texture throughout the storage time, however burnt odor on UV-C light treated chicken samples was detected on day 1 of storage. Similar off-odor on the chicken samples immediately after UV-C treatment was previously reported by McLeod et al. (2018). Further sensory evaluation during storage by the focus group revealed that the burnt odor was no longer noticeable on samples stored for 5 and 7 days.

Sensory evaluation was conducted on cooked untreated (control) and UV-C treated chicken meat samples using hedonic test with 90 participants. Cooking the chicken samples was done to mimic normal practices in chicken consumption. The result of hedonic test showed that UV-C light surface pasteurisation had no impact ($p>0.05$) on the appearance, flavor, texture, juiciness, and overall acceptance of both cooked skinless and skin-on chicken samples throughout refrigerated storage (data not shown). The burnt odor detected on day 1 of storage by the focus group on raw UV-C treated chicken samples was not detected on the cooked product and similar impact of cooking on odor fading was reported by McLeod et al. (2018). Similar work done by Park & Ha (2015) showed no effect on sensory attributes of UV-C treated (60 mJ cm^{-2}) skinless chicken breast samples. The results of sensory evaluation in this study showed that UV-C light surface pasteurisation had no impact on the sensory attributes of fresh chicken meat stored for seven days at (4°C).

4. CONCLUSION

The result of this study suggested that UV-C light surface pasteurisation dosage of 50 mJ cm^{-2} has the potential to extend the shelf-life of fresh skinless chicken meat portions without significant impact on both sensorial and physicochemical attributes. The result also suggested that UV-C light processing was not effective for the surface pasteurisation of fresh skin-on chicken meat portions.

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10:30 AM - 10:45 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room C)

[4-1015-C-02] Efficient Filtering of Live *Escherichia coli* by Using 60 GHz CMOS Sensor

*Hiroki Fukuda[1], Tetsuhito Suzuki[1], Naoshi Kondo[1], Yuichi Ogawa[1] (1. Graduate School of Agriculture, Kyoto University(Japan))

Keywords: Bacteria separation, 60 GHz CMOS sensor, Dielectrophoresis, E. coli

The separation and extraction of bacteria are essential for food safety evaluation and infection diagnosis by a blood test. In particular, the quick selection of live and dead bacteria can contribute to developing efficient and high precision bacterial testing. To realize this, we have been developing a near-field array CMOS sensor with a 60 GHz oscillator. 1488 oscillators are arranged in 3 mm square, and when the sample exists on the surface, the distribution of the electric field on the sensor surface changes and the resonance frequency also changes. We succeeded in mounting the circuit of dielectrophoresis (DEP) in each oscillator by CMOS integration technology. In this presentation, we report the investigation of the optimization of applied voltage and frequency to this DEP circuit in order to distinguish live and dead bacteria.

The cultured *E. coli* suspension was centrifuged twice to replace the medium and distilled water. This *E. coli* suspension was used as a measurement sample of viable bacteria. Also, 5 ml of this suspension was placed in an autoclave for 1 hour to make dead bacteria. And the oscillation frequency of two samples of live and dead bacteria was measured every 6 seconds for 300 seconds. In the measurement, the sample was flowed at 5 μ L / min with a syringe pump (YWC). In addition, DEP was set to a voltage of 5 V and a frequency of 10, 100, and 1000 kHz. DEP was turned off from 0 to 60 seconds, DEP was turned on from 60 to 240 seconds, and DEP was turned off from 240 to 300 seconds. The experiment was conducted while confirming the presence of *E. coli* on the CMOS sensor with a microscope.

The oscillation frequency at 240 seconds minus the oscillation frequency at 300 seconds was taken as the frequency shift. At DEP 10 kHz, it is thought that no live bacteria or dead bacteria were affected by the negative DEP force and bacteria did not accumulate on the oscillator. At DEP 100 kHz, a positive force of DEP acts on the live bacteria, and the live bacteria are accumulated on the oscillator, and the shift of the live bacteria is considered to be 0.015 GHz. It is thought that bacteria did not accumulate on the oscillator because negative DEP force was exerted on dead bacteria. At DEP 1000 kHz, it is thought that positive DEP force acts on both live and dead bacteria, and bacteria accumulate on the oscillator. From this experiment, the possibility of distinction between live and dead bacteria of *E. coli* was shown at DEP 100 kHz.

Oral Session | Food Safety
[4-1015-C] Food Safety (1)
Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room C (3rd room)

[4-1015-C-03] Safety Evaluation of Bacteriocinogenic Strains of *Pediococcus acidilactici* Isolated From Artisanal Cheeses

Luis Augusto Nero[1], Yosep Ji[2], Wilhelm Holzapfel[2], *Svetoslav Dimitrov Todorov[1] （1. Universidade Federal de Viçosa(Brazil), 2. Handong GLobal University(Korea)）

Keywords: Pediococcus acidilactici, bacteriocins, virulence factors

Total DNA extracted from bacteriocinogenic *Pediococcus acidilactici* ST1607V, ST2104V and ST3105V, was been screened for presence of more than 50 genes related to production of biogenic amines (histidine decarboxylase, tyrosine decarboxylase and ornithine decarboxylase), virulence factors (sex pheromones, gelatinase, cytolisin, hyaluronidase, aggregation substance, enterococcal surface protein, endocarditis antigen, adhesion of collagen, integration factors) and antibiotic resistance (vancomycin, tetracycline, erythromycin, gentamicin, chloramphenicol, bacitracin). *Pediococcus acidilactici* ST1607V, ST2104V and ST3105V presented low frequencies of presence for virulence genes. Only few genes were detected in some strains, indicating their safety for application in fermented food products. Besides all beneficial properties studied for various LAB, most considered as GRAS, a special attention need to be addressed on the possible presence of virulence factors, production of biogenic amines and antibiotic resistance. Results from appropriate biochemical tests and detected main genes associated to virulence factors and antibiotic resistance in LAB strains, could be considered as potential hazard of application of this organisms in food products. Moreover, additional *in vitro* and *in vivo* experiments must be designed in the system simulating fermentation processes or GIT conditions in order to investigate deeper the possible expression of the present virulence genes.

Safety Evaluation of Bacteriocinogenic Strains of *Pediococcus acidilactici* Isolated From Artisanal Cheeses

Luis Augusto Nero[1], Yosep Ji[2], Wilhelm Holzapfel[2], Svetoslav Dimitrov Todorov[1,2,*]

[1.] Departamento de Veterinária, Universidade Federal de Viçosa, Campus UFV, 36570-900, Viçosa, MG, Brazil
[2.] Advanced Green Energy and Environment Institute (AGEE), Handong Global University, Pohang, Gyungbuk 791-708, South Korea

*Corresponding author: email address slavi310570@abv.bg

ABSTRACT

Total DNA extracted from bacteriocinogenic *Pediococcus acidilactici* strains ST1607V, ST2104V and ST3105V, was screened for the presence of more than 50 genes related to the production of biogenic amines (histidine decarboxylase, tyrosine decarboxylase and ornithine decarboxylase), virulence factors (sex pheromones, gelatinase, cytolysin, hyaluronidase, aggregation substance, enterococcal surface protein, endocarditis antigen, adhesion of collagen, integration factors) and antibiotic resistance (vancomycin, tetracycline, erythromycin, gentamicin, chloramphenicol, bacitracin). *Pediococcus acidilactici* ST1607V, ST2104V and ST3105V presented low frequencies of presence for virulence genes. Only a few genes related to safety were detected in some strains, indicating their safety for application in fermented food products. In addition to the beneficial properties widely studied and reported for various lactic acid bacteria (LAB), most are considered as GRAS generally recognized as safe) organisms. However, special attention should be given to the presence of possible virulence factors, in addition to the production of biogenic amines and antibiotic resistance. Results from appropriate biochemical tests and based on major genes associated with virulence factors and antibiotic resistance, may serve to identify a potential hazard before application in food products. Moreover, additional *in vitro* and *in vivo* experiments could be designed for simulating fermentation processes and/or GIT conditions in order to determine possible expression of detected virulence genes.

Keywords: *Pediococcus acidilactici,* Bacteriocins, Virulence factors

1. INTRODUCTION

Application of LAB is well accepted in different areas of bio-preservation of food products such as starter or adjunct cultures for control of spoilage microorganisms. Traditionally, LAB have a long history of safe use and association with fermentations of food products from plant, meat and dairy origin. On the basis of empiric knowledge appropriate safe cultures are being isolated and selected for appropriate applications. Different LAB strains are part of numerous fermented food products from different geographical regions. However, even if numerous studies report on their beneficial properties (probiotics, starter and biopreservation cultures), only a limited number of studies have focused thus far on the safety of these strains. The majority of the LAB strains, especially of *Lactobacillus* spp., *Pediococcus* spp. and *Lactococcus* spp., have been Generally Recognized as Safe (GRAS) for human and animal applications based on their historical safety record and applications in different food fermentations. However, scanning the existing literature it is scarcely realized that some clinical cases of infection were linked to some LAB strains (Goldstein et al., 2015).

One of the essential factors in evaluation of safety of beneficial LAB in the future is the presence of virulence factors in addition to (transferable) antibiotic resistance. Absence of genes related to virulence factors has become a most important criterion in the safety evaluation of LAB. Beneficial LAB carrying virulence genes, especially of easy transferable genetic material, can be involved in a spreading of these genes via horizontal transfer to other bacteria, including to some relevant human and animal pathogens. It is thus imperative to know the potential virulence related gene profile of such beneficial LAB strains, and thereby prevent them serving as potential reservoirs of resistance genes that can result in th generation of potentially hazardous strains (Todorov et al., 2019).

In this work we explore safety aspects of 3 bacteriocinogenic strains of *Pediococcus acidilactici* isolated from artisanal cheese in Brazil, related to the presence of genes associated to virulence, antibiotic resistance and production of biogenic amines in addition to basic antimicrobial properties.

2. MATERIALS AND METHODS

2.1. Isolation of bacteriocin producers from cheese

Screening for bacteriocin-producing isolates was carried out according to the triple-agar-layer method described by Todorov & Dicks (2005). Samples of 50 g each of artisanal cheeses obtained from the local market (Vicosa, MG, Brazil), were macerated with 450 ml sterile saline (0.85%, w/v NaCl) in a Stomacher (BagMixer, Interscience, Weymouth, USA) for 10 min at 20 °C. Serial dilutions of the sample were made with sterile saline, plated onto MRS agar (Difco). The second layer of agar (1.0 %, w/v) was supplemented with 50.0 mg/L Actidion (Sigma) to prevent fungal growth. All plates were incubated at 37 °C for 24 h. Colonies were then overlaid with a third layer of 1% (w/v) Brain Heart Infusion (BHI) agar (Difco), seeded with 10^6 CFU/mL of *Listeria monocytogenes* 711. The plates were incubated at 37 °C for 24 h. Colonies with the largest zones of growth inhibition were isolated, inoculated into MRS broth (Difco) and incubated at 30 °C for 24 h. Pure cultures were obtained by streaking onto MRS agar.

Antimicrobial activity was confirmed by using the agar-spot-test method (Todorov, 2008). Activity was expressed as arbitrary units (AU) per mL, with one AU defined as the highest dilution showing a clear zone of inhibition (Todorov, 2008). *L. monocytogenes* 711 was used as a sensitive test strain.

One mL of a cell-free supernatant, prepared as described before, was added to 1 mg/mL of α-amylase (Sigma Diagnostics, St. Louis, MO, USA), Proteinase K (Roche, Indianopolis, IN, USA) and pronase, lipase or catalase (Roche), respectively. Samples were incubated at 30 °C for 30 min and then heated at 95–97 °C for 5 min. The pH of all samples was adjusted to 6.0 and bacteriocin activity determined with *L. monocytogenes* 711 as sensitive strain, as described above.

2.2. Identification of strains

Identification was conducted by physiological and biochemical tests (Stiles & Holzapfel, 1997). Carbohydrate fermentation reactions were recorded by using API 50 CHL (Biomérieux, Marcy-I'Etiole, France). Total DNA from the selected strains was isolated using the ZR Fungal/Bacterial DNA Kit (Zymo Research, Irvine, CA, USA) following the instructions of the manufacturer. DNA concentration was determined on NanoDrop (ThermoFisher Scientific Inc., Waltham, MA, USA). Differentiation of the strains was performed by random amplification of polymorphic DNA (RAPD) PCR. Primers OPL-02 and OPL-08 were used (Kit L of the RAPD® lomer kits, Operon Biotechnologies, Cologne, Germany). Amplification reactions were performed according to Todorov et al. (2010). The amplified products were separated by electrophoresis in 1.4% (w/v) agarose gels in 1x TAE buffer at 100V for 2 h. Gels were stained in TAE buffer containing 0.5 µg/mL of ethidium bromide (Sigma Diagnostics, St. Louis, Mo., USA).

Identification of the studied strains was performed by amplifying the genomic DNA with primers F8 (5'-CAC GGA TCC AGA CTT TGA TYM TGG CTC AG-3') and R1512 (5'-GTG AAG CTT ACG GYT AGC TTG TTA CGA CTT-3'), as described by Felske et al. (1997). The amplified fragments were cleaned using SigmaSpin™ Post-Reaction Clean-Up Columns (Sigma, St Louis, MO, USA), sequenced, and compared to sequences in GenBank using BLAST (Basic Local Alignment Search Tool).

2.3. Detection of virulence genes:

All PCR reactions were performed using the GeneAmp® PCR Instrument System 9700 (Applied Biosystems, Foster City, USA). All strains were tested for presence of virulence genes: production of gelatinase (*gel*E), hyaluronidase (*hyl*), aggregation substance (*asa*1), enterococcal surface protein (*esp*), cytolysin (*cyl*A), endocarditis antigen (*efa*A), adhesion of collagen (*ace*), vancomycin resistance (*van*A, *van*B, *van*C1, *van*C2, *van*C2/C3), erythromycin resistance (*erm*A, *erm*B, *erm*C), tetracycline resistance (*tet*K, *tet*L, *tet*M, *tet*O, *tet*S), related to gentamycin resistance (*aac*(6')-Ie-*aph*(2")-Ia), aminoglycosides resistance (*aph*(3')-IIIa, *ant*(4')-Ia, *aph*(2'')-Id, *aph*(2'')-Ic, *aph*(2'')-Ib, *ant*(6)-Ia), chloramphenicol resistance (*cat*A), bacitracin resistance (*bcr*B, *bcr*D, *bcr*R), production of sex pheromones (*ccf*, *cob*, *cpd*), serine protease (*spr*E), transposon related (*int*, *int*Tn) and genes for amino acid decarboxylases: *hdc*1 and *hdc*2 (both related to histidine decarboxylase), *tdc* (tyrosine

decarboxylase), and *odc* (ornithine decarboxylase), using PCR protocols of Moraes et al. (2012) and Fortuna et al. (2008).

3. RESULTS AND DISCUSSION

Based on inhibition zones of *L. monocytogenes* 711, 17 isolates were selected for future study. The selected isolates showed strong inhibitory activity against 30 different *L. monocytogenes* strains.

RAPD-PCR analysis with primers OPL-02 and OPL-08 (data not shown) showed differences among the 17 isolates and clearly established 3 distinct clusters. According to these results the 3 isolates (one from each cluster: ST1607V, ST2104V and ST3105V) were selected for future study. The 16S rRNA amplified from selected 3 strains revealed 98-99% homology to the 16S rRNA sequence of *P. acidilactici*.

The bacteriocins ST1607V, ST2104V and ST3105V were inactivated by treatment with the tested proteolytic enzymes, but not with α-amylase, lipase or catalase. This suggested that the activity of bacteriocins ST1607V, ST2104V and ST3105V was a direct effect of an antimicrobial proteinaceous metabolite.

The bio-molecular screening for presence of 50 virulence genes showed that *P. acidilactici* strains ST1607V, ST2104V and ST3105V carried at least a few virulence genes. However, no evidence for the presence of *asa1, aac(6')-Ie-aph(2")-Ia, aph(2")-Ic, aph(2")-Id, hdc1, hdc2, tdc, ddlE, bcrD, catA, ant(6)-Ia, aph(2")-Ib, aph(3')-IIIa, ace, cob, cpd, cyt, ermA, gelE, tetK, tetM, tetS, vanB, int* in any of the 3 tested strains was recorded (Table 1). Moreover, the observed frequency of putative virulence factors in *P. acidilactici* strains ST1607V, ST2104V and ST3105V was lower than that reported in other studies on *Lactobacillus* spp., *Enterococcus* spp., *Pediococcus* spp. isolated from foods (Todorov et al., 2014; Todorov et al., 2019), also in comparison with studies on clinical isolates (De Sousa, 2003). 12, 14 and 12 from 50 tested virulence genes were detected in *P. acidilacticii* strains ST1607V, ST2104V and ST3105V, respectively. In a previous study (Todorov et al., 2019) *P. acidilactici* ET35 isolated from smoked salmon was described to be positive for 14 virulence genes, including *cytA, efaA, ermA, ermB, ermC, tetO, aph(2")-Ic, vatE, bcrB, ccf, cob, int-Tn, vanA and vanC2*.

Studying virulence factors has always been a focus of investigation on pathogenic bacteria related to clinical isolates. Special attention has been given to *Enterococcus* spp. as some strains are considered as opportunistic pathogens. However, some other LAB, including *Pediococcus* spp., can carry virulence factors as well and even if they are not expressed, such strains have to be considered as potential health hazards since under specific conditions they may either express these virulence factors, or the genetic information can be transferred to other bacterial species. Moreover, the determination of virulence factors in LAB by molecular and phenotypic procedures needs to be considered as an important, compulsory aspect, due to the risk of genetic transfer, since these features are usually encoded by genes located in conjugative plasmids. LAB in general have a remarkable long history as beneficial organisms, used in different fermentation processes for centuries and have found increased application as probiotics in the last few decades (Martinez et al., 2012). However, some strains, especially belonging to species of th genera *Enterococcus* and *Streptococcus*, are considered as opportunistic pathogens and can be associated with some clinical cases (Goldstein et al., 2015).

Spreading of antibiotic resistance genes are strain and gene specific (Table 1). Resistant strains to different antibiotics have been also identified, and several genes encoding such resistance have been identified and studied; e.g., different erythromycin-resistance genes (*erm*) have been found in many species of LAB, as well as a number of tetracycline resistance genes – *tet*(K, M, O, Q, S, W) (Dicks et al., 2011). Rojo-Bezares *et al.* (2006) reported that *ant*(6), *aph* (3′)-IIIa and *tet*L genes were found in *Pediococcus* spp. strains. The aminoglycoside resistance gene *aac*(6')-Ie-*aph*(2'')-Ia has been reported for some *Pediococcus* species from animal and wine origin, including *P. pentosaceus* and *P. parvulus* (Tenorio et al., 2001). Genetic determinants for macrolide resistance [*erm*(AM) genes] have been reported for *P. acidilactici* strains (Tankovic et al., 1993), and one of these genes was found to be encoded on a 46-kbp non-transferable plasmid (Tankovic et al., 1993). An *erm*B gene has been associated with a plasmid in a *P. acidilactici* strain (Danielsen et al., 2007). Bacterial cells can use a variety of mechanisms to share and spread resistance determinants. In natural environmental conditions the main mechanisms for horizontal gene transfer in bacteria are conjugation and transduction via bacteriophages (Kleinschmidt et al., 1993). Even with only limited information available regarding the pediococci and native conjugation systems, this scenario is not impossible.

Formerly, the transfer of genetic material - plasmid and transposoms from LAB to LAB and from LAB to other Gram-positive or Gram-negative bacteria - has been reported (Dicks et al., 2011). These strains belonging to the genus *Enterococcus* are well known for their ability as natural acceptors during th conjugation process (Clewell and Weaver, 1989). This scenario may also be possible for *Pediococcus* strains as well.

Table 1. Presence/absence for virulence factors, antibiotic resistance and biogenic amine production in *Pediococcus acidilactici* strains ST1607V, ST2104V isolated from artisanal cheeses in Brazil.

	ST1607V	ST2104V	ST3105V
esp	+	+	-
efaA	+	-	+
ermB	-	+	-
ermC	-	-	+
tetL	-	+	-
tetO	-	+	-
ant(4')-Ia	+	+	+
vatE	-	+	-
bcrB	+	-	-
aac(6')-Ii	-	+	-
ccf	+	+	+
fsrA	+	-	+
fsrB	-	-	+
fsrC	-	+	-
vanA	-	-	+
vanC1	+	-	+
vanC2	+	+	+
vanC1(2)	+	-	+
vanC1/C2	+	-	-
odc	-	+	-
bcrR	+	-	+
hyl	+	+	-
mur2ed	-	+	-
mur2ef	-	+	-
sprE	-	-	+
asa1, aac(6')-Ie-aph(2")-Ia, aph(2")-Ic, aph(2")-Id, hdc1, hdc2, tdc, ddlE, bcrD, catA, ant(6)-Ia, aph(2")-Ib, aph(3')-IIIa, ace, cob, cpd, cyt, ermA, gelE, tetK, tetM, tetS, vanB, int	-	-	-

Positive results (+) for genes for virulence, biogenic amines and antibiotic resistance in *P. acidilacticii* strains ST1607V, ST2104V and ST3105V

4. CONCLUSION

P. acidilacticii strains ST1607V, ST2104V and ST3105V have been isolated from artisanal cheeses in Brazil, and showed bacteriocinogenic activity against *Listeria* strains. Attention needs to be given to safety aspects for each strain before recommendation as starter, bio-preservative or probiotic culture for human or animal application. Low level presence of virulence factors related genes can be considered as a positive feature for the studied LAB strains. However, additional *in vitro* and *in vivo* experiments need to be designed in a systematic approach for simulating food processing and/or GIT conditions for determining possible expression of the few virulence genes present.

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Oral Session | Food Safety
[4-1015-C] Food Safety (1)
Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room C (3rd room)

[4-1015-C-04] Sensitivity Comparison of Standard and real-time PCR Assay for Detection *Salmonella* Typhimurium and Enteritidis in Indonesian Chicken Carcasses

*siti nurjanah[1,2], Winiati Puji Rahayu[1,2], Ratih Dewanti-Hariyadi[1,2] (1. Department of Food Science &Technology, Bogor Agricultural University (IPB University)(Indonesia), 2. SEAFAST Center, Bogor Agricultural University (IPB University)(Indonesia))

Keywords: chicken carcasses, real-time PCR, Salmonella Enteritidis, Salmonella Typhimurium, sensitivity

Salmonella is a pathogenic bacterium that can cause serious illness to humans. Chicken carcasses have been reported contaminated by *Salmonella,* especially *S.* Typhimurium and *S.* Enteritidis. Rapid and sensitive method for detection and differentiation of both species is required. The objective of this study was to compare the sensitivity of standard and real-time PCR (rt-PCR) assay for detection and differentiation two *Salmonella* serovars using pre-enrichment and enrichment treatment. Primer from invA gene, specific Typhimurium protein (STM) and specific Enteritidis virulence plasmid (Prot6E) sequences were used for marker of *Salmonella* genus, *S.* Typhimurium and *S.* Enteritidis respectively. Sensitivity determination was carried out by artificially contaminated of each *Salmonella* serovars into chicken carcasses approximately amount of 10^5 CFU/mL. After contaminated, DNA was extracted by chelex100 method and subsequently one-tenth dilution up to lowest concentration. Sensitivity was determined based on the lowest amount of DNA remain detected then converted to the cells number. The result showed that rt-PCR was more sensitive for genus detection. Without pre-enrichment step, the limit detection of rt-PCR for *Salmonella* genus, *S.* Typhimurium and *S.* Enteritidis were equivalent with 3.8×10^1 cells, 4.1×10^3 cells, and 2.6×10^4 cells respectively, meanwhile the standard PCR for each were equivalent with 5.3×10^4 cells, 4.0×10^4 cells, 4.1×10^3 cells respectively. Both of methods were applied to detect 20 *Salmonella*-contaminated chicken carcasses; rt-PCR assay can detected all of positive samples, whereas standard PCR showed 3 false negatives results. However, both of method showed similar results for detection serovars *S.* Typhimurium and *S.* Enteritidis. Pre-enrichment step in buffer phosphate for 8 hours increased the sensitivity of standard PCR until less than 10 cells even for two serovars detection. It' s concluded that analysis by standard PCR required pre-enrichment step for obtaining the sensitive result.

Sensitivity Comparison of Standard and real-time PCR Assay for Detection *Salmonella* Typhimurium and Enteritidis in Indonesian Chicken Carcasses

Siti Nurjanah[1,2]*, Winiati P. Rahayu[1,2], Ratih Dewanti-Hariyadi[1,2],

[1]*Department of Food Science and Technology, Bogor Agricultural University (IPB University) Indonesia*
[2]*Southeast Asian Food and Agricultural Science and Technology (SEAFAST) Center, Bogor Agricultural University (IPB University), Indonesia*
**Corresponding author e-mail addresses: sity_nr@apps.ipb.ac.id*

Abstract

Salmonella is a pathogenic bacterium that can cause serious illness to humans. Chicken carcasses have been reported contaminated by *Salmonella,* especially *S.* Typhimurium and *S.* Enteritidis. Rapid and sensitive method for detection and differentiation of both species is required. The objective of this study was to compare the sensitivity of standard and real-time PCR (rt-PCR) assay for detection and differentiation two *Salmonella* serovars using pre-enrichment and enrichment treatment. Primer from invA gene, specific Typhimurium protein (STM) and specific Enteritidis virulence plasmid (Prot6E) sequences were used for marker of *Salmonella* genus, *S.* Typhimurium and *S.* Enteritidis respectively. Sensitivity determination was carried out by artificially contaminated of each *Salmonella* serovars into chicken carcasses approximately amount of 10^5 CFU/mL. After contaminated, DNA was extracted by chelex100 method and subsequently one-tenth dilution up to lowest concentration. Sensitivity was determined based on the lowest amount of DNA remain detected then converted to the cells number. The result showed that rt-PCR was more sensitive for genus detection. Without pre-enrichment step, the limit detection of rt-PCR for *Salmonella* genus, *S.* Typhimurium and *S.* Enteritidis were equivalent with 3.8×10^1 cells, 4.1×10^3 cells, and 2.6×10^4 cells respectively, meanwhile the standard PCR for each were equivalent with 5.3×10^4 cells, 4.0×10^4 cells, 4.1×10^3 cells respectively. Both of methods were applied to detect 20 *Salmonella*-contaminated chicken carcasses; rt-PCR assay can detected all of positive samples, whereas standard PCR showed 3 false negatives results. However, both of method showed similar results for detection serovars *S.* Typhimurium and *S.* Enteritidis. Pre-enrichment step in buffer phosphate for 8 hours increased the sensitivity of standard PCR until less than 10 cells even for two serovars detection. It's concluded that analysis by standard PCR required pre-enrichment step for obtaining the sensitive result.

Keywords: chicken carcasses, real-time PCR, *Salmonella* Enteritidis, *Salmonella* Typhimurium, sensitivity

11:15 AM - 11:30 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room C)

[4-1015-C-05] Development of Calculation Framework for Stochastic Prediction of Uncertainty and Variability in Survival Spore Numbers during Non-isothermal Inactivation by Second-order Monte Carlo Simulation

*Hiroki Abe[1], Kento Koyama[1], Kohei Takeoka[1], Shinya Doto[1], Shuso Kawamura[1], Shige Koseki[1] (1. Hokkaido University(Japan))

Keywords: Predictive microbiology, Dynamic model, Stochastic model, Bootstrap method, Markov chain Monte Carlo, Weibull model, Thermal inactivation

Although thermal inactivation is one of the control measures for microbial contamination in foods, thermal processing at a high temperature or long-time heating induces chemical and physical reactions in foods that reduce product quality. To determine minimum processing condition, mathematical models need to appropriately describe the bacterial behavior during inactivation; the log-linear model, generally used, based on *D*-value (Decimal reduction time) would lead to overestimation or underestimation of thermal death time. In addition, the conventional kinetic predictive models disregard the variability and uncertainty of bacterial death behavior, although various mathematical models (log-linear or non-log-linear models) have been used to describe reduction behaviors during bacterial inactivation. In this context, “uncertainty” represents the lack of perfect knowledge of the parameter value; “variability” represents the true heterogeneity of the population that is a consequence of the physiological system. The importance of uncertainty and variability of biological and natural phenomena is widely recognized in the context of the guidance of quantitative microbial risk assessment. Few studies have been performed to separately evaluate and describe the variability and the uncertainty in population dynamics of microbial inactivation. This study aimed to develop a stochastic bacterial survival model considering both the “variability” and “uncertainty” from kinetic data. The developed model estimates the variance of survival behavior during non-isothermal inactivation. Furthermore, the estimated bacterial death behaviors were validated with the observed survival counts data. The spores of *Bacillus simplex* were heated under fifteen isothermal conditions (pH: 5.4, 5.8, 6.2, 6.6 and 7.0; Temperature: 80, 85 and 90° C); the changes in the survival spore count were experimentally determined. The uncertainty in fitted Weibullian parameters was estimated from statistical resampling one thousand replicates of the survival spore counts in each thermal condition by the non-parametric bootstrap method. One thousand replicates of the secondary models were described by estimated parameters. The secondary models describe the relationship between Weibullian parameters and pH and/or heating temperature. In contrast, individual cell heterogeneity of the death spore counts in an infinitesimal time interval was described as “variability” by Markov chain Monte Carlo (MCMC) method based on a binomial distribution. The second-order Monte Carlo (2DMC) simulation estimated the changes in the survival spore behavior during non-isothermal heating with both the variations. In parallel, the variance in survival kinetics of survival spore counts during non-isothermal heating was observed to compare with the prediction of survival counts. The uncertainty of the Weibullian parameter estimations and individual heterogeneity of the death spore counts in an infinitesimal time interval was successfully described. Furthermore, in all of three non-isothermal histories, the variances in the survival spore counts during processing periods were successfully described by the developed 2DMC model. The MCMC successfully described stochastic results in the bacterial reduction behaviors during not only isothermal but also non-isothermal from kinetic data. In conclusion, the 2DMC model enabling to describe both the uncertainty and variability in thermal inactivation will play an important role in appropriate risk assessment for bacterial survival.

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[4-1015-C] Food Safety (1)
Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room C (3rd room)

[4-1015-C-06] Evaluation Growth Characteristics of Bacterial Spores Combine Treatment with High Hydrostatic Pressure and Alkaline Electrolyzed Water

*Koki Morita[1], Taiga Kuhara[1], Yoshinori Kamitani[1], Daisuke Hamanaka[1] (1. Kagoshima University faculty of agriculture(Japan))

Keywords: Bacterial spores, high hydrostatic pressure, Alkaline electrolyzed water, Injured microbes, Gonpertz curves, Antibiotics

In our previous study, we observed that the heat resistance of bacterial spores was effectively reduced by the combining treatment with high hydrostatic pressure(HHP) and alkaline electrolyzed water(AlEW). However, it is not clear in detail the effect of bacterial spores treated with AlEW and HHP, especially behavior of injured microbes which can live but cannot growth normally with the delay of lag phase etc. Since the existence of injured microbes may cause underestimate of viable counts comparing with the actual number of survived cell, correct understanding of growth characteristic is important to evaluate the microbiological safety of food. The growth curve of the microorganism is sigmoid and is divided into four phases; lag phase, accelerated log phase, slowed log phase and stationary phase. Gompertz curves are often used as continuous equation to represent sigmoidal growth curves. Growth of injured microbes is well known to affect growth characteristics, including delay of lag phase and reduction of growth rate as compared to those of intact one. In this study, we investigated the evaluation of injury characteristics by the double culture method supplemented with antibiotics in growth media, and growth behavior of bacterial spores treated by AlEW, HHP and their combination using Gompertz equation to obtain parameters in growth curve.Bacterial spores used in this study were *Bacillus subtilis* NBRC3134. Bacterial spores ware formed by conventional method and suspended in sterile sterile physiological saline (PS) to treat HHP.Contacting treatment of bacterial spores with AlEW was performed by suspending in test solution in plastic tube, and centrifuged. The pellet of bacterial spores on the bottom of plastic tube were re-suspended by vigorous pipetting and vortex-shaking. This process was performed two times, and treated spores were finally suspended with PS solution. PS solution was used as a control.Spore suspension was poured into plastic bag without air for following treatment.HHP treatments were performed with 100MPa for 1 hour at 50℃.The HHP treated pouch was aseptically opened, an appropriate amount of spore suspension was inoculated trypticase soy broth (TSB) supplemented with Chloramphenicol (CP) or Penicillin (PCG) for evaluation of the injury characteristics related to synthesizes of protein(enzyme) or peptidoglycan, and incubated at 30℃ for 48 hours. The optical density of the inoculated TSB at 490nm was measured every 30 minutes.Gompertz equation was fitted to the obtained OD data by nonlinear least squares method to obtain various parameters.At the same time, the growth behavior of AlEW and HHP treated bacterial spores were evaluated by calculating the length of lag phase and their difference between control and treated sample.So far, the investigation of the changes in growth characteristics of microorganisms have been reported and, it is known that shortening and extension of lag phase, fluctuation of growth rate in log phase, and difference in maximum viable count in stationary phase are affected. In this study, normal culture media and media supplemented with antibiotics were used as recovery media for injured cells produced by high-pressure-based treatments with or without AlEW, and their growth characteristics were compared with those of intact bacteria. The period of lag phase bacterial spores was not significantly different between high-pressure-treated and untreated sample, but significant extension of lag phase was obtained by the combination with AlEW. In addition, further extensions of lag

phase in growth curve were observed when a medium supplemented with CP or PCG was used. On the other hand, there were small differences between the treated and untreated samples in both the growth rate in log phase and maximum number of bacterial cell even in the case of CP or PCG supplementation. In general, extension of the lag phase in growth behavior is considered to be a process of recovery of injured bacteria. Moreover, the difference in growth rate in the log phase and the difference in the maximum number of viable cells in the stationary phase are considered to be the result of changes in the nutrient requirement of the microorganism related to the stress treatment. CP and PCG are antibiotics with features that inhibit protein and peptidoglycan synthesis, respectively. Considering the results obtained in this study, bacterial spores treated with high pressure treatment with and without AlEW require the time duration for recovering from damage associated with the synthesis of some essential biopolymers, but nutritional requirements and other phenotypic properties might not be affected.

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Original Research Article

Evaluation Injury Characteristics of *Bacillus* Spores by Combination of Hydrostatic Pressure with Alkaline Electrolyzed Water

Koki Morita[1], Masaki Naka[1], Ai Tomomatsu[1], Kyohei Arimura[2], Yoshinori Kamitani[1], and Daisuke Hamanaka[1] *

[1] Department of Agriculture, Kagoshima University:1-21-24 Korimoto, Kagoshima-shi, Kagoshima, 8900065 Japan
[2] Kagoshima-Osumi Food Technology Development Center, 4938 Hosoyamada, Kushira, Kanoya, Kagoshima, 8931601 Japan

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ABSTRACT

The effect of combing procedures of high hydrostatic pressure (HHP) with alkaline electrolyzed water (AlEW) on the injury characteristics of bacterial spores were investigated. Effective reductions of survival *Bacillus subtilis* spores combined treatment of AlEW with HHP were obtained by the following heat shock at 80°C for 15 min. No survivals were observed by 100MPa of HHP treatment. Approximately 90 to 99% of bacterial spores treated by HHP with AlEW were injured or lost heat resistance since 1 to 2 logs difference in the survival comparing with the unheated bacterial spores were obtained. Double culture method (DCM) for assessing the injury characteristics of bacterial spores was performed by using trypticase soy broth supplemented with chloramphenicol (CP) and rifampicin (RFP), which are related to the synthesis inhibition of protein and RNA, respectively. Severe injury of the treated bacterial spores assessed by RFP supplemented broth were obtained at 50 and 100MPa with and without AlEW. Especially at 50MPa, considerable synergistic effect of AlEW on spore injury was observed. These results suggested that injury associated with the biosynthesis of some enzymes was observed at relatively low pressure level.

INTRODUCTION

Thermal processing is a major method for reducing the number of microorganisms in various food commodities. However, huge amount of thermal energy for inactivating bacterial spores, which are often existing in various agricultural commodities and has high resistance against physical stresses, results in the degradation of internal/external quality of fresh/processed foods such flavor, texture, surface color, functional components, and so on (Miyamoto et al., 2009). In order to reduce the negative effect on the quality of foods by thermal energy, various non-thermal antimicrobial technologies have been investigated for the actual application as an alternative. Whereas there are disadvantages about the inactivation process of bacterial spores (Ogino et al., 2015), high hydrostatic pressure (HHP) treatment has been focusing as the useful technology with small degradation of food

* *Corresponding author.* Tel.: +81-99-285-3558 fax: +81-99-285-3558
E-mail address: hamanaka@chem.agri.kagoshima-u.ac.jp

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quality.

Bacterial spores have high resistance against various chemical and physical stresses as described, it is well known that the injured or germinated bacterial spores induced by chemical/physical treatment lost their resistance against the following antimicrobial processes without severe condition (Sonoike et al., 1997). Several researchers reported that HHP also has a potential for reducing heat resistance of bacterial spores (Tsutido et al., 1992). Comparing with single heat treatment, additional 3-4 logs reduction of bacterial spores, previously treated by a 200MPa of HHP at 50°C for 10 min, was obtained by 80°C (Bartlett et al., 2002). The further reduction of pressure level is really important for considering about the application of HHP antimicrobial processing to the food industry by appropriate combining procedure of additional technologies.

In our previous study, we obtained the combination of HHP with alkaline electrolyzed water (AlEW), generated by electrolysis of diluted saline solution in a cathode side of diaphragm tank, has a potential to reduce the heat resistance of bacterial spores. Whereas the reduction of heat resistance was considered a result from spore injury by the combining treatment, the detailed mechanisms of the injury process had not been elucidated.

Double culture method (DCM) using standard culture media, such as trypticase soy agar; TSA, with/without typical growth-inhibiting agents has been used the determination of the number of the injured cell treated by an inactivation process. DCM is useful for the evaluation of the number of injured cell, however, there are some disadvantages for the clarification of detail mechanisms of injury process. For the further understanding of the injury characteristics of bacterial spores treated by AlEW with HHP, the modified DCM was required to be applied.

In this study, we investigated the evaluation of injury characteristic of bacterial spores treated by AlEW, HHP and their combination using DCM applied with antibiotics supplemented growth media.

MATERIALS AND METHODS

Test bacterium and preparation of spore suspension

Bacterial spores used in this study were *Bacillus subtilis* NBRC3134 obtained from National Institute of Technology and Evaluation (NITE). Stocked culture of *B. subtilis* were transferred to trypticase soy broth (TSB, Becton Dickinson and Company, USA), and cultured at 30°C for 24 hours. A 0.1 mL of cultured broth was applied and spread onto standard method agar (SMA, Nissui Pharmaceutical Co. Ltd., Tokyo) plates supplemented with 1g/L of $MgSO_4 \cdot 7H_2O$ and incubated at 30°C for 7 days for spore formation. Spores were collected by flooding the cultured agar surface with sterile physiological saline (PS) solution, and then scraping the surface with a sterile glass rod. Harvested spores were washed three times in sterile PS solution by centrifugation at 3500×g for 10min, followed by heat treatment at 70°C for 1 hour in order to kill the vegetative type cells. The spore concentration of prepared suspension was approximately 10^8-10^9 colony forming unit per milliliter (CFU/mL).

AlEW contracting treatment

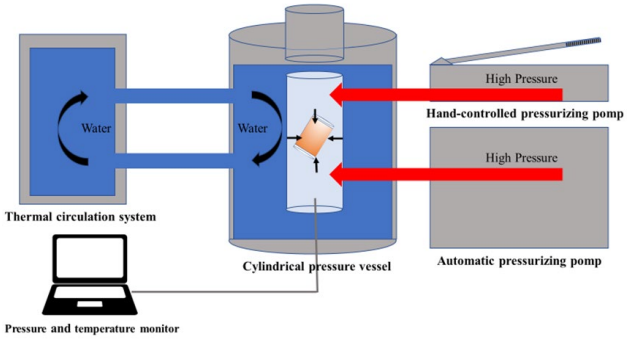

Fig.1. Schematic diagram of pressurization apparatus

AlEW was generated using an electrolysis apparatus (ROX-20TA, HOSHIZAKI Electric Co. Ltd., Aichi, Japan). The current passing through the electrolysis apparatus was set at 10A, and the voltage between the electrodes was set at 10V. Oxidation reduction potential and pH were -835mV and 11, respectively. Physiological saline (PS) solution was used as a control water.

Contacting treatment of bacterial spores with AlEW was performed by suspending in test solution in plastic tube for 1 min, and centrifuged at 3500×g for 5 min. The pellet of bacterial spores on the bottom of plastic tube were re-suspended by vigorous pipetting and vortex-shaking for 3 min. This process was performed two times, and treated spores were finally suspended with PS solution.

HHP treatment

A 5 mL of spore suspension was poured into plastic bag without air, and aseptically heat sealed for preparing 2x5 cm^2 pouch for following treatment. HHP treatment was immediately performed by the pressurization apparatus (Fig. 1, Echigo Seika Inc., Niigata, Japan) with a cylindrical pressure vessel (inside volume = 300mL). Internal temperature of vessel was controlled by thermal circulation system (LBX-350, AS ONE, Co., Osaka, Japan) at 50°C. HHP conditions were prepared by the combined pressurization system equipped both automatic and hand-controlled pressurizing pump connected to the vessel. HHP treatments were performed with 30, 50 and 100MPa for 1 hour. Internal pressure and temperature during treatment were monitored by sensors equipped in the vessel. Rates of pressurization and depressurization were approximately 20MPa/sec and 100MPa/sec, respectively.

Evaluation of spore survival

The treated pouch was cooled down to ambient temperature immediately, and aseptically opened by sterile scissors. Treated suspension was transferred to glass test tube, and performed heat shock at 80°C for 15min in the electric heating block in order to kill the injured cell. A 1 mL of spore suspension was serially diluted by PS, and a 0.1mL was applied and evenly spread onto TSA plate. TSA plates were incubated at 30°C for 24 hours, and the survival counts were calculated by the number of colonies appeared after incubation.

Evaluation of injury characteristics of bacterial spores

The treated pouch was cooled down to ambient temperature immediately, and aseptically opened by sterile scissors. A 0.1 mL of spore suspension was inoculated TSB supplemented with chloramphenicol (CP, Wako Pure Chemical Co., Saitama, Japan) or rifampicin (RFP, Wako Pure Chemical Co.), for evaluation of the injury characteristics related to synthesizes of protein (enzyme) or RNA, respectively. The concentration of CP and RFP in TSB were 100ppm, which is the maximum level without influence on the growth of *B. subtilis* spores used in this study. After incubation for 24 hours, a 200mL of cultured media was transferred into microtiter plate, and the optical density (OD) at 600nm was measured by microtiter plate reader (Elx800UV, Biotek Instruments, Inc., Vermont, USA).

Injury characteristics of bacterial spores were determined by injury ratio (I_R) calculated by following equation;

$$I_R = \frac{N_I - N_{AI}}{N - N_A}$$

Where I_R is the injury ratio to the intact spores. N, N_I, N_A and N_{AI} are ODs of cultured pure TSB inoculated with untreated bacterial spores, cultured TSB supplemented with antibiotics inoculated with the untreated bacterial spores, cultured pure TSB inoculated with HHP treated bacterial spores, and cultured TSB supplemented with antibiotics inoculated with HHP treated bacterial spores, respectively. In case the calculated value of IR is more than 1, it was considered that some specific properties of bacterial spores were influenced by single or synergistic effect of AlEW, HHP and its combination.

All experiments were performed triplicate and the means of spore survival and injury ratio were calculated.

RESULTS AND DISCUSSION

It is well known that microbicidal efficiency of HHP treatment accelerate as increase in the pressure level. In this study, HHP treatment with 100MPa had a potential to inactivate bacterial spores comparing with that with 30MPa as shown in Figure 2. In addition, 0.5-1.5 logs reduction of spore survival were obtained by the combination of AlEW regardless of the difference in the pressure level. Approximately 90-95% of bacterial spores were injured and lost heat resistance by single AlEW or HHP and its combination under 50MPa, because the heat shock treatment at 80°C for 15min inactivate 1-1.5 logs of bacterial spores at 30 and 50MPa. On the other hand, all bacterial spores pressurized at 100MPa both with and without AlEW

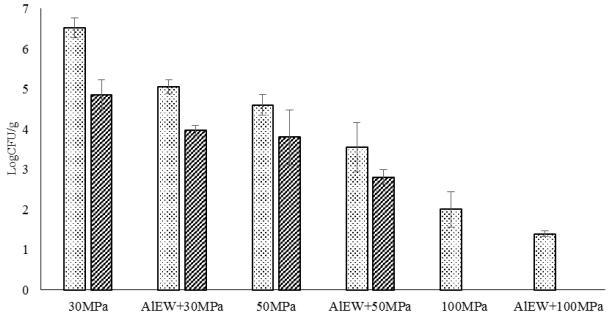

Fig. 2 Survival of bacterial spores treated with/without alkaline electrolyzed water and high hydrostatic pressure followed by heat treatment. ▦: before heating, ▨: after heating

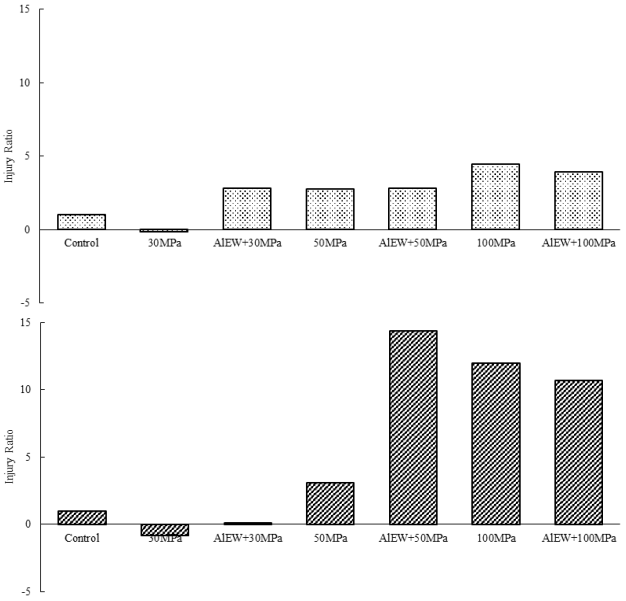

Fig. 3. Injury ratio of *Bacillus subtilis* spores treated by HHP with or without AlEW cultured with Chloramphenicol (▦) or Rifampicin (▨) supplemented trypticase soy broth.

could be injured and lost heat resistance since no survivals were obtained by a heat shock treatment at 80°C.

In DCM procedure, as the injury assessment of bacteria treated by some bactericidal technology, typical growth agar media salt-supplemented or water activity-controlled were generally applied for the recognition of the difference in the counted number of the appeared colonies. However, typical colony counting procedure was difficult to understand the injury characteristics of the stressed bacteria. Therefore in this study, the optical densities of growth culture broth supplemented with two antibiotics of CP and RFP before/after incubation were applied to the evaluation of injury characteristics of bacterial spores. CP and RFP have specific inhibiting influences on the protein (enzyme) and RNA synthesizes, respectively, and the injury characteristics could be assessed by the differences in the sensitivities of injured and intact bacterial cells.

Figure 3 shows the calculated injury ratio obtained from the measured OD values of TSB supplemented with CP and RFP. The higher sensitivities of treated bacterial spores against CP supplemented broth were obtained in comparison with the control sample, AlEW treatments did not have synergistic effect on the injury ratio at more than 50MPa. High injury ratios of the treated bacterial spores assessed by RFP supplemented broth were also obtained at 50 and 100MPa with and without AlEW. Especially at 50MPa, considerable synergistic effect of AlEW on spore injury was observed. These results suggested that injury related to the biosynthesis of proteins such as enzymes was observed at relatively low pressure level, whereas the injury related to RNA synthesis was influenced by slightly higher pressure level. Further studies are needed to clarify the mechanisms of the synergistic efficiencies observed at 30MPa with CP broth and at 50MPa with RFP broth. It was considered that AlEW synergistic effect could appeared under slightly stressed conditions for bacterial spores.

Although most of microorganisms are injured when exposed to

various stresses, it is well known that microbes have a potential to develop a specific function corresponding to the type of stress and recover as it can grow normally (Tsuchido et al., 1999). Considering about HHP treatment, typical injury of bacterial cells could be the enzyme denaturation and the destruction of cell membrane during physical process. The combination of AlEW might accelerate the injury of bacterial spores related HHP treatment.

CONCLUSIONS

In this study, it was obviously clarified that the HHP treatment is injured in synthesis of protein and RNA, and the combination of AlEW is increased the efficient of injury to bacterial spores. However, further investigations are strongly required for the clarification of the relationship between HHP and AlEW injury characteristics and reduction of heat resistance. The analysis of molecular level such as gene expression would be important to evaluate the detail mechanism of HHP injury. Introducing appropriate technology for the inactivation of bacterial spores using HHP has great potential for manufacturing various kinds of food with better quality and safety. The reduction of pressure level with ensuring food safety would reduce the cost, and expected to be applied to any food industries in near future.

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Oral Session | Food Safety
[4-1015-C] Food Safety (1)
Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room C (3rd room)

[4-1015-C-07] Impact of Mechanization Development on Women and Hired Labor Utilizations of Small-Scale Rice Farming Operations in Kampar Region, Indonesia

*UJANG PAMAN[1], Khairizal Kha, Hajry Arief Wahyudy （1. RIAU ISLAMIC UNIVERSITY(Indonesia)）
Keywords: Mechanization development, women labor, hired labor, small-scale rice farming

Agricultural mechanization has been undergoing the development process through the replacement of human labor and draught animals with farm machinery particularly in rice farming system. This research examines the impact of mechanization development on women and hired labor utilization of small-scale rice farming operations in Kampar Region. Field surveys were conducted in two districts in Kampar Region, namely Kuok and Bangkinang during July-August 2018. Sixty rice women farmers were purposively selected for samples and they were interviewed personally to collect primary data. Data were analyzed using a descriptive–quantitative approach and simple regression techniques. As a result, the mechanization development in small-scale rice farming gradually reduced women and hired labor utilization and quickly occurred primarily on labor-intensive operations, such as land preparation, harvesting, threshing, and milling. Totally, the time requirement for performing rice farming operations was relatively high to account for 602.56 $hr.ha^{-1}$. Most of the hours were required to perform manually operations, including weeding (136.31 $hr.ha^{-1}$), transplanting (132.59 $hr.ha^{-1}$), and harvesting (99.77 $hr.ha^{-1}$). These operations required more time due to dominantly worked by women and hired labor with manual tools. On the other hand, the working hours used farm machines reduced significantly, accounting for 61.88 $hr.ha^{-1}$, 99.76 $hr.ha^{-1}$, 30.27 $hr.ha^{-1}$, and 45.92 $hr.ha^{-1}$ for ploughing, harvesting, threshing, and milling, respectively. The reduced working hours in rice farming created few off-farm activities in survey areas

Impact of Mechanization Development on Women and Hired Labor Utilizations of Small-Scale Rice Farming Operations in Kampar Region, Indonesia

Ujang Paman[1*], Khairizal[1], Hajry Arif Wahyudy[1]

[1]Department of Agricultural Economic and Agribusiness, Faculty of Agriculture,
Riau Islamic University, Pekanbaru, Indonesia
*Corresponding author: E-mail: pamanu@agr.uir.ac.id

ABSTRACT

Agricultural mechanization has been undergoing the development process through the replacement of human labor and draught animals with farm machinery particularly in rice farming system. This research examines the impact of mechanization development on women and hired labor utilization of small-scale rice farming operations in Kampar Region. Field surveys were conducted in two districts in Kampar Region, namely Kuok and Bangkinang during July-August 2018. Sixty rice women farmers were purposively selected for samples and they were interviewed personally to collect primary data. Data were analyzed using a descriptive–quantitative approach and simple regression techniques. As a result, the mechanization development in small-scale rice farming gradually reduced women and hired labor utilization and quickly occurred primarily on labor-intensive operations, such as land preparation, harvesting, threshing, and milling. Totally, the time requirement for performing rice farming operations was relatively high to account for 602.56 $hr.ha^{-1}$. Most of the hours were required to perform manually operations, including weeding (136.31 $hr.ha^{-1}$), transplanting (132.59 $hr.ha^{-1}$), and harvesting (99.77 $hr.ha^{-1}$). These operations required more time due to dominantly worked by women and hired labor with manual tools. On the other hand, the working hours used farm machines reduced significantly, accounting for 61.88 $hr.ha^{-1}$, 99.76 $hr.ha^{-1}$, 30.27 $hr.ha^{-1}$, and 45.92 $hr.ha^{-1}$ for ploughing, harvesting, threshing, and milling, respectively. The reduced working hours in rice farming created few off-farm activities in survey areas.

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1. INTRODUCTION

Women have long been recognized as an important labor force in rural economies around the world. They hold a crucial role in agricultural and rural development (Petrics et al., 2018) and key players in the agricultural sector (Enete and Amusa, 2010; Kumar and Kumari, 2018). Women are involved in over half of the farm activities in most developing countries (Bayisenge et al., 2019) and encompass the largest percentage of the workforce in the agricultural sector (Assefa and de Roo, 2015). Women have made greatly contribution to about 43% of the agricultural labor force in the agricultural sector globally and it rises to be 70% in some developing countries (FAO, 2011: Team and Doss, 2011; Petrics et al., 2018). The figures ranged from 15- 81% in Southeast Asia and 42% in Indonesia (Paris, 2006). However, the current agricultural transformation toward mechanized farming system has had a different impact on women labor contribution in agricultural sector and changed rapidly in many parts of the world (Sisei, 2016).

The vital role of women in agricultural production of most developing countries particularly in rice farming operations has been reported by a number of studies (Enete and Amusa, 2010; Ajadi, et al., 2015; Baba et al., 2015; Cisco, 2016; Sisei, 2016; Amare and Endalew, 2016; Sims and Kienzle, 2016). They revealed that women have been involved in the whole farm operations from land preparation to post-harvest processing with different rates of contribution. However, the involvement of women in rice production varies from region to region and even within regions (Fonjong and Athanasia, 2007; Effiong et

al., 2015). Moreover, the involvement of women differs with difference of agro-production systems (Bala, 2010) and also varies from land preparation to post harvest operations (Sucharita and Bishnoi, 2018).

Traditionally, the roles of rural women were such as household maintenance, cooking, fetching drinking water, and fuel wood (Santhi et al., 2005), while in rice production included planting, weeding, harvesting, processing, and rice post-harvest activities (Waris, 2015; Sucharita and Bishnoi, 2018). For instance, in Western Uttar Pradesh, India, women have engaged in most of the agricultural operations except ploughing and their participation depend on the labor requirement for various crops (Baliyan, 2018). In Nigeria, women mostly participated in post farming operations such as harvesting, storage, watering, and transporting (Olawepo and Fatulu, 2012). In the same country, Yusuf et al. (2014) stated that the contribution of the women ranges from tasks as land clearing, land tilling, and planting, weeding, fertilizer/manure application to harvesting, food processing, and threshing.

The rapid development of agricultural mechanization today through the introduction of new technologies especially farm machinery has brought about changes in farming system in most developing countries. The important process of the mechanization development is to replace human labors and draught animals by mechanical devices (farm machinery) in farming activities (Simalenga, 2000; Chandrasekaran et al., 2008, Akinbamowo, 2013; Basu and Nandim 2014; Reddy et al., 2014; Paman et al., 2018). In Adamawa state, for example, the human power is gradually replaced by single axle multipurpose machines from land preparation to post- harvest (Mada and Mahai, 2013). According to Diao et al., (2014), the agricultural mechanization represents technology change through the adoption of mechanical power to undertake agricultural operations such as ploughing, harvesting, shelling, and planting. This development process may withdraw women labor early out of the farming activities because they commonly operate manual tools to perform farm works and eventually had a major impact on the demand and supply for farm labor (Schmitz and Moss, 2015).

Farm works physically demand much power and the working conditions are often harsh (Srivastava, 2006). Under these conditions, mechanization technology is essential for agricultural production and processing (Mlengera et al., 2015) in order to take the drudgery out of such hard work (Kienzle et al, 2013; Mujawamariya and Kalema, 2017; Sucharita and Bishnoi, 2018; Namdeo, 2018), which makes a difficulty for women labor to manually perform of the operations. Currently, the mechanization is required not only for increasing crop production, but also for processing and along the entire value chain (Sims and Kienzle, 2017). Furthermore and most importantly, mechanization can also help to perform for very difficult tasks in agriculture with short time and less cost (Basu and Nandi, 2014), so the introduction of mechanization implements and technologies enables to lighten burden of women (Amare and Endalew, 2016). Hence, farm machinery has become increasingly available on farm and highly required primarily for rice farming operations in rural area today.

The displacement of women labor and together with hired labor in agricultural activities as a result of mechanization development has been a common phenomenon in most developing countries, including Indonesia. The widespread use of the farm machinery has had serious equity consequences in terms of the displacement of labor and tenant farmers (Pingali, 2007). Kirui (2019) reported that tractor-powered mechanization had significant effects on the use of family and hired labor. In Indonesia, women still hold a central role in the agriculture activities in the country, particularly in rice production as well as post-harvest processing. The present research examines the impact of mechanization development on women and hired labor utilization in small-scale rice farming operations in Kampar Region.

2. MATERIALS AND METHODS

Kampar Region is divided into 21 districts that widely spread on area of 1,128,928 hectares. According to Food Crops Services of Kampar Region (2018), plantation area is dominant in the region to reach 415.702 hectares (approximately 37% of total), consisting of palm oil, rubber, coconut, crops, and other plantation crops, and the second dominant area is forestry to reach 76,853 hectares (6.81% of total). While, paddy field area has 6.546 hectares (0.58% of the total) and spreads only over 15 districts and the areas are mostly rain-fed paddy field. Although rice is not a main crop in the region, it is an important

crop to provide stable food for feeding population especially in the region. Therefore, local government greatly supports rice farmers to enhance production and productivity through more intensively application of farm machinery to perform farming operations.

Rice in Kampar Region is grown on both irrigated and rain-fed paddy field areas and cropping season can be once or twice a year depending on type of land and climatic conditions. Wet (rainy) season is main cropping season of rice in Kampar region i.e., during October – March. The second cropping season is on dry season, i.e., during April – August every year. The duration of both seasons included one month for land preparation before rice transplanting. Interview with farmers revealed that the whole rice areas are usually cultivated during wet season due to supply water from rainfall is sufficient mainly the beginning of growing season to facilitate land preparation.

From 21 districts in Kampar Region, there are fifteen districts to have paddy field areas that produce rice every year. These districts are important areas to supply local rice need in the region. The field survey was conducted only in the two districts, namely Kuok and Bangkinang which were purposively selected from fifteen districts of the region. Two villages then were selected from each selected districts with a total of four villages. The areas selected for the survey are based on their high level of farm machinery application with a high role of human and hired labor in the rice production activities.

The population of the research consisted of small rice farmers from four selected villages in the Kampar Region. Fifteen small rice farmers were randomly selected from each village for samples making a total of sixty rice farmers. Most of the samples are women who directly involve in rice farming cultivation. This research used primary data which were collected by personal interview method with the farmers using a structured questionnaire after the main cropping season of 2018. Data collected consisted of sample characteristics, working hours of men, women, hired labors, and machines for each type of rice farming operations, rice farming areas, and rice yields. The data collected thus were tabulated and analyzed by using descriptive-quantitative appropriate such as percentage, median and simple regression technique.

3. RESULTS AND DISCUSSION

3.1. Characteristics of samples and rice farms

As outlined in advance, sample farmers in this research were women who directly involved in rice farming cultivation. They were 46 years old and had 8 years of formal education on average. Rice cultivation has been carried out from generation to generation as the main source of livelihood and provided rice food mainly for household consumption. Therefore, the farmers have a long time of experience in rice cultivation to average 17 years. The number of family members was 5 persons on average, consisting of parent and three children. Most of farmers did not employ their children in rice farming activities because they go to school in their villages or in the city out of the village.

The rice farm owned farmers in survey areas is characterized by small-scale area, ranging from 0.11 to 1.00 hectares. Most farmers divided their farm areas into small plots with an average of 250 m^2 per plot (ranging from 107 m^2 to 2,500 m^2). This was done to be easier for doing tillage work when they previously used manual tool (hoe) and to make easily supply water into the field. Consequently, farmers slightly experienced a difficulty to perform tillage work by machine. Few farmers could not fully use the machine to perform the operations due to too small size of the farm holdings. The time requirement to complete the tillage work was still relatively longer as a result of the use of farm machines was still limited. Beside small farm size, the insufficient water supply into paddy field also constrained the application of farm machines for rice farming in the Kampar Region.

3.2. Labor and machine utilization

Type of farm machines which have popularly been used by small rice farmers in Kampar Region are hand tractors, combine harvesters, power threshers, and rice milling units (RMUs) (Figure 1). They have been gradually replacing traditional tools like hoes, sickles, pedal threshers, etc. with farm machines.

According to Paman et al. (2014), these farm machines are mostly managed by hire service providers for small rice farmers. There is not many farmers to own farm machines themselves due to low purchasing power. Therefore, majority of small farmers harnessed farm machinery service providers to work their farming operations. In practices, the application level of the machines in rice farming operations varied not only among districts or rice growing areas but also between individual farmers. The level of the machinery application among farmers depended on farmer's economic ability to pay machinery services, availability of family labors, size of farm holdings, and farmers' age. For instance, small farmers who have enough money replaced most family women and hired labor with farm machines. The main reason is to shorten operation time and improve work quality of rice farming. The using of farm machines enables farmers in the same area to plant rice at the same time to hinder pest attack like bird, rat etc. Consequently, the utilization of both women and hired labor gradually reduced in the survey areas.

Rice production is a labor-intensive operation with fluctuating workload depending on operation type of farming. In practices, labor is usually required much more and very hard for plowing, planting, harvesting, threshing, and milling operations. Therefore, these operations were replaced more early than other ones, like seedling, weeding, pest and disease control, transporting, and drying. In survey areas, these operations were worked by either human and hired labor or farm machines. It was found that approximately 90% of farmers fully used farm machines (hand tractor) to perform land preparation, whereas this operation was previously worked manually by either women or hired labor. About 20% and 72% of farmers used farm machines to perform both harvesting and threshing operations, respectively. The milling operation has fully mechanized and farmers did not employ women and hired labor for that operation anymore in the survey areas.

Figure 1. Type of farm machines used by small rice farmers di Kampar Region

Table 1 shows that totally, time requirement for rice farming operations was about 602 hr.ha^{-1}. This finding is smaller than 851 hr.ha^{-1} as reported by Paman et al. (2012) for Riau Province in 2012 (Kampar is one of 12 regions of the Riau Province). It means that there was a decrease of the required time for rice farming operations per hectare to approximately 29% during the last 7 years. Furthermore, the most time required for weeding was 136.31 hr.ha^{-1}, followed by transplanting (132.59 hr.ha^{-1}) and then harvesting (99.77 hr.ha^{-1}). These operations required more time due to dominantly worked by human labor. Hitherto, the farm machine for performing above operations have been not available yet, except for harvesting such as combine harvester.

Four labor intensive operations which have mostly been taken over by farm machines included plowing, harvesting, threshing, and milling. The operations were worked with requiring shorter time to account to 61.88 hr.ha^{-1}, 99.76 hr.ha^{-1}, 30.27 hr.ha^{-1}, and 45.92 hr.ha^{-1} for plowing, harvesting, threshing, and milling, respectively. Ploughing, harvesting, and threshing operations have not fully mechanized yet. The contribution of farm machines was about 61%, 3%, 67% for ploughing, harvesting, and threshing, respectively. Meanwhile, the milling was worked completely by small rice milling units (RMUs)/hullers. Now, both harvesting and threshing operations could be done together with combine harvester, so time requirement would be relatively shorter.

Table 1. Labor requirement for rice farming operations in hour per hectare

Type of operation	Family Labor		Hired Labor		Machine	Total
	Man	Woman	Man	Woman	($hr.ha^{-1}$)	($hr.ha^{-1}$)
Ploughing	13.74	14.80	0.00	0.00	33.34	61.88
Seedling	2.94	10.47	0.00	0.00	0.00	13.41
Transplanting	23.20	90.77	0.00	18.62	0.00	132.59
Fertilizing	3.30	34.41	0.00	0.00	0.00	37.71
Weeding	15.93	110.12	0.18	12.28	0.00	136.31
Pest and disease control	4.04	16.32	0.00	0.00	0.00	20.35
Harvesting	11.38	64.04	4.42	16.96	2.97	99.76
Threshing	0.00	9.87	0.00	0.00	20.40	30.27
Transporting	7.49	3.58	0.00	0.00	0.00	11.07
Drying	1.39	11.89	0.00	0.00	0.00	13.28
Milling	0.00	0.00	0.00	0.00	45.92	45.92
Total	83.41	356.40	4.60	47.86	82.23	602.56

Referring to Paman et al., (2015), there were three types of hand tractors have been popularly used for land preparation i.e., moldboard ploughs, rotary tillers, and hydro tillers. The use of these farm machines depend on field conditions primarily water supply on the paddy field. Both rotary tillers and hydro tillers were used under condition of the water supply into paddy field is sufficient where the water on the surface of field is flooding. Therefore, they were commonly used during wet growing season.

Furthermore, combine harvester has begun to be used for harvesting and threshing operations, although this machine is just in its infancy in survey areas today. Previously, the above operations were worked dominantly by women or hired labors with sickles for harvesting and pedal threshers for threshing. Consequently, the displacement of women and hired labors with machine caused to reduce significantly human labor utilization in rice farming operations. Interview with farmers revealed that land preparation required time at least 25 – 30 working days by human labor, this time reduced significantly to be only 2 - 3 days by hand tractors. Other operations that were also replaced by machines also required shorter and shorter time.

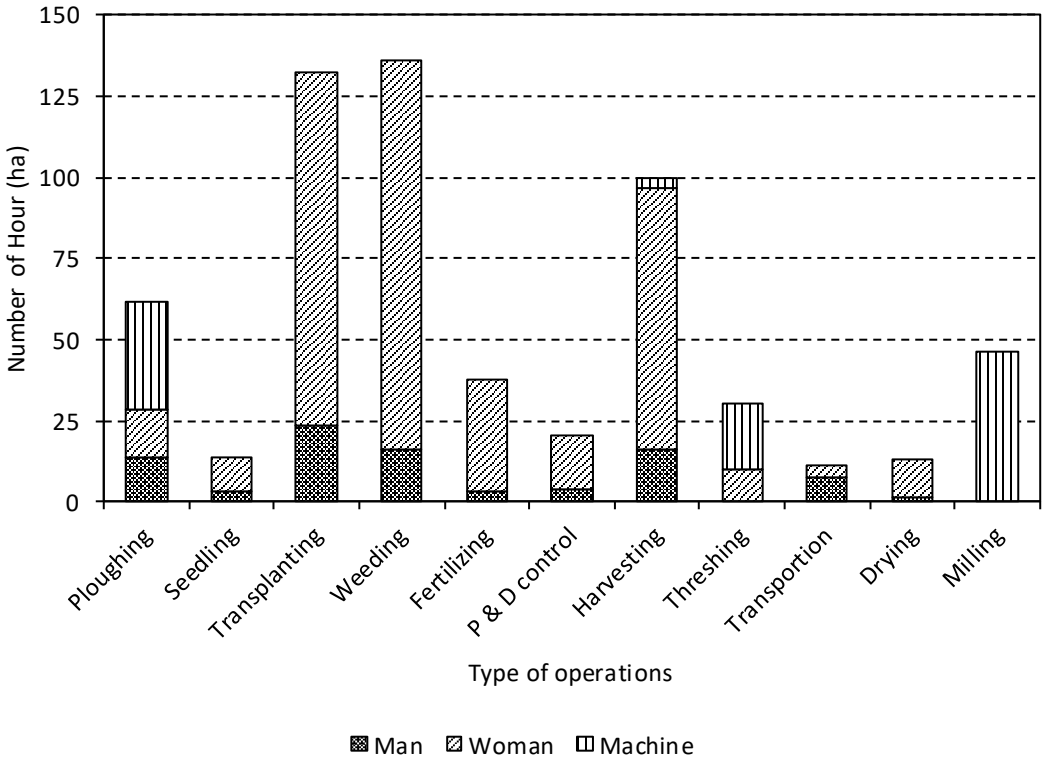

Figure 2. Contribution of human labor and machinery in rice farming operations

The contribution of woman labor as well as man labor in rice farming operations varied among types of operations as presented in Figure 1. The milling operation did not involve family women as well as hired labor anymore and the operation was completely worked by rice milling units (RMUs). This operation replaced by machine quicker than other ones and reached full mechanized today. It is because many milling service providers offering cheap price are available in survey areas. Plowing, harvesting, and threshing operations still involved women although their contributions have gradually being reduced. For instance, the contribution of women labor remained only 32% and 28% for plowing and threshing, respectively. Current introduction of mini tractors and combine harvesters will replace women labor soon in the future in survey areas. Other operations were still dominated by women, exception transportation.

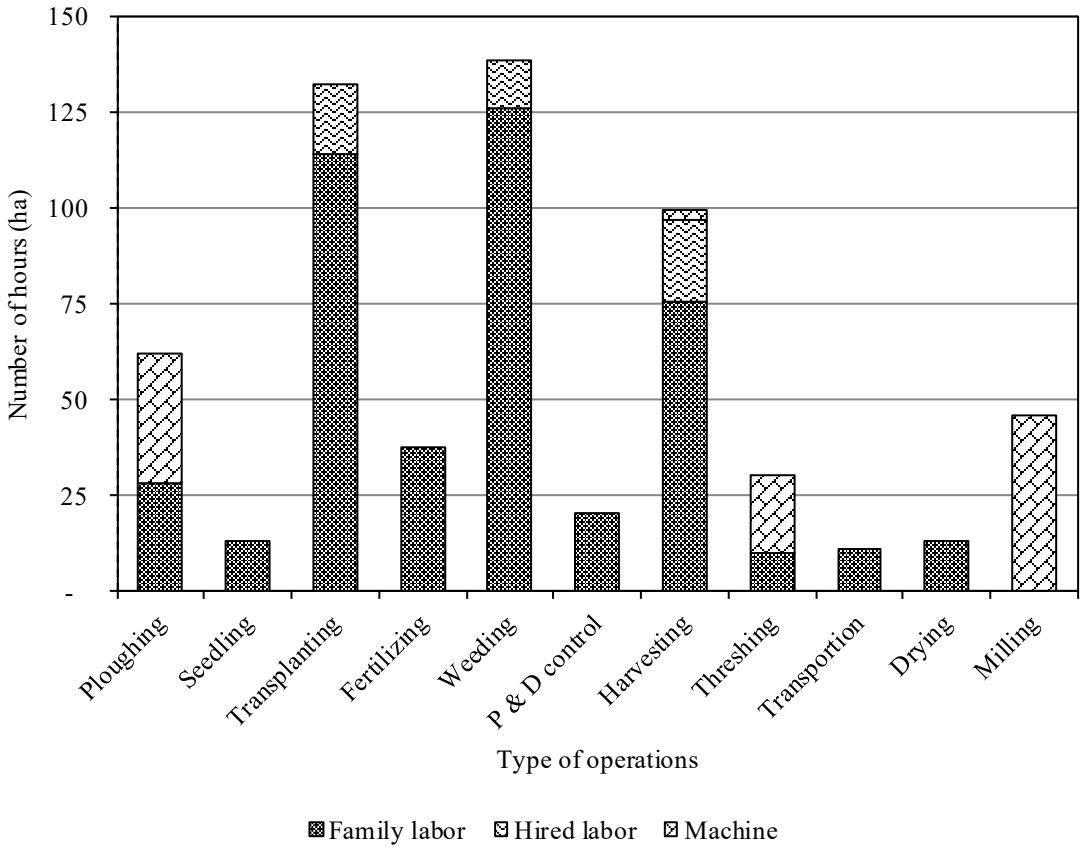

Figure 3. Contribution of hired labor and machinery in rice farming operations

According to Figure 2, the involvement of hire labors in rice farming operations in survey areas was only in transplanting, weeding and harvesting operations. Previously, the hired labors were mostly required in ploughing before being replaced by machine. While, for light and easy operations were commonly worked by family labors such seedling, fertilizing etc. The contribution of hired labor in transplanting, weeding and harvesting operations was relatively lesser to account for about 16%, 10%, and 28%, respectively. In this case, the hired labors were mostly woman, while men farmers were not so interested to be hired labor on rice farming due to low wage rate. The hired labors commonly worked 8 hours per day and were paid based on working day basis. The prevailing rates of wage which were established by farmer community in survey areas are IDR 100,000 (US $7) per working day for man labor and IDR 80,000 (US $6) per working day for woman labor under exchange rate of IDR 14,000 per US dollar. Most farmers revealed that the rate of wage did not increase during the last 4 years due to unchange significantly price of rice product.

The impact of mechanization development on both working hour of women and hired labors per hectare can be graphically illustrated in Fig. 4 and 5. The mechanization level in this analysis is the rate of machinery application in farming operations. A simple linear regression was used to relate between working hour of women and mechanization level. The linear regression could explain 45% ($r = 0.45$) of the observed variation in working hour of women and showed a negative relationship between working hour of women per hectare and mechanization

level as described by equation: $y = -0.030x + 24.401$. The result indicates that working hour of women per hectare tended to decrease with increasing mechanization level.

Figure 4. Relationship between mechanization level and working hours of women

Similarly, the relationship between mechanization level (y) and working hour of hired labors (x) per hectare also showed a negative and had a lower correlation. It means that the higher level of mechanization in farming operation caused the reduction of using hired labors. However, the decrease in working hour of hired labors could only explain 34% as shown by linear regression ($y = -0.038x + 20.119$; $r = 0.34$). The other factors that may cause the reduction of working hour of hired labors such as the rate of labor wage, availability of hired labors in the village, and etc. that did not include in the regression model.

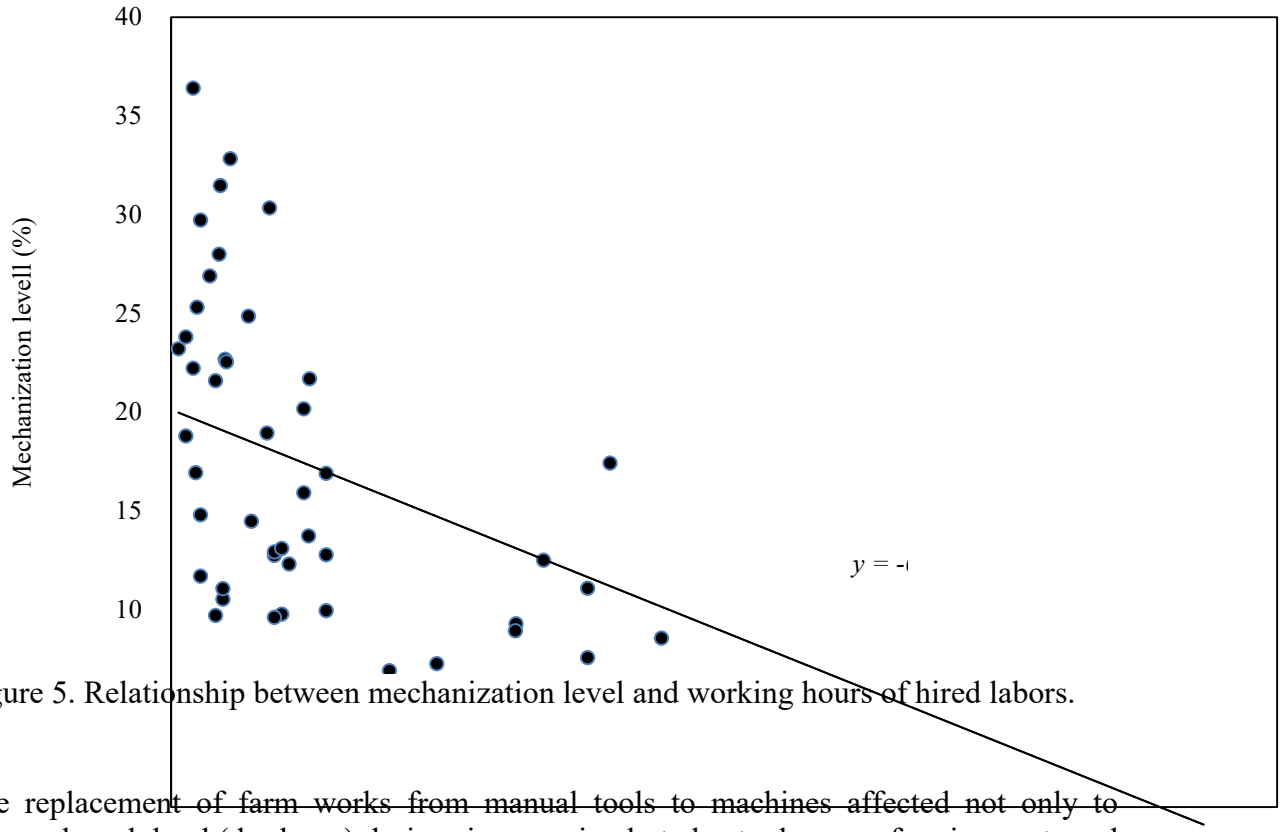

Figure 5. Relationship between mechanization level and working hours of hired labors.

The replacement of farm works from manual tools to machines affected not only to reduce time and work hard (drudgery) during rice growing but also to decrease farming costs and additional farmer's income for hired labor. The reducing cost of rice farming was significance and improved efficiency of farm management. Based on interviews with farmers revealed that cost of land preparation reached IDR 2,500,000 (US $143) per hectare by human labor. If this operation is worked by hand tractor, it was required only IDR 1,500,000 (US $107) per hectare or decreased about 25%. This cost referred to the rate of service charge for hiring machine from local farm machinery providers.

The reduced working hours in rice farming of women as well as hired labors lead them to create new job opportunities. They did off-farm activities such as fruit trading, making cake, etc. However, some women used the spare time to help their husband to work on non-rice farm activities such as oil palm, rubber, and orange garden. Furthermore, most of older women who aged more than 60 years old made use of time to take a rest. They felt tired to work in rice farming because this activity has been done since young (approximately 15 years old). They also wish to take the opportunity for participating much more in social and religion activities in their neighborhood.

4. CONCLUSIONS

The present research concludes that the rice farming operations have gradually used machines to replace women and hired labors primarily for labor-intensive operations, including land preparation, harvesting, threshing, and milling. The application rate of the farm machines was different between individual farmers as well as type of operations. Totally, the time requirement for performing rice farming operations was relatively high to be 602.56 $hr.ha^{-1}$. Most of the hours were required to perform manually operations such as weeding (136.31 $hr.ha^{-1}$),

transplanting (132.59 hr.ha^{-1}), and harvesting (99.77 hr.ha^{-1}). These operations required more time due to dominantly worked by women and hired labor with manual tools. On the other hand, the operation hours that used farm machines reduced significantly, accounting for 61.88 hr.ha^{-1}, 99.76 hr.ha^{-1}, 30.27 hr.ha^{-1}, and 45.92 hr.ha^{-1} for ploughing, harvesting, threshing, and milling, respectively. The working hours of women and hired labor per hectare tended to decrease with increasing farm machines application. Reduced working hours in rice farming has created few off-farm activities although some of them still work on non-rice farming and partly take a rest at home especially for older farmers.

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Oral Session | Food Quality

[4-1015-D] Food Quality (1)

Chair:Yutaka Kitamura(University of Tsukuba, Japan), Mizuki Tsuta(National Agriculture and Food Research Organization)

Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room D (4th room)

[4-1015-D-01] Effects of Operational Conditions of Internal Combustion Furnace on rice husk Biochar and vinegar

*WEI-PUO KUO[1], YUTAKA KITAMURA[2], Yoshiyuki HARA[4], CHING-CHEN HSIEH[3], YI-HUNG LIN[3], CHEN-PIN CHEN[1] （1. Taiwan Agricultural Machinery and Biomechatromics Engineering Technology Development Association(Taiwan), 2. University of Tsukuba(Japan), 3. National Pingtung University of Science and Technology(Taiwan), 4. Hokkaido Agricultural Experiment Station(Japan)）

10:15 AM - 10:30 AM

[4-1015-D-02] Assessment of Red Tomato Freshness Using Ultraviolet-induced Fluorescence Image

*Keiji Konagaya[1], Dimas Firmanda Al Riza[1], Minori Yoneda[1], Sen Nie[1], Takuya Hirata[2], Noriko Takahashi[2], Makoto Kuramoto[2], Tetsuhito Suzuki[1], Naoshi Kondo[1] （1. Kyoto Univ.(Japan), 2. Ehime Univ.(Japan)）

10:30 AM - 10:45 AM

[4-1015-D-03] Thermal oxidation stability assessment of extra virgin olive oil using fluorescence and transmittance imaging system

*Vincent Rotich[1], Dimas Firmanda Al Riza[1], Ferruccio Giametta[2], Tetsuhito Suzuki[1], Yuichi Ogawa[1], Naoshi Kondo[1] （1. Kyoto University(Japan), 2. University of Molise(Italy)）

10:45 AM - 11:00 AM

[4-1015-D-04] Chalkiness Index of Sake Rice “Yamada Nishiki” Using Ultraviolet-Near-Infrared Transmission

*Khokan Kumar Saha[1,2], Firmanda Al Riza Dimas[1], Yuichi Ogawa[1], Tetsuhito Suzuki[1], Naoshi Kondo[1], Takuma Sugimoto[3] （1. Lab of Bio-sensing Engineering,Graduate School of Agriculture, Kyoto University, Kitashirakawa-Oiwakecho,Sakyo-ku ,606-8502.(Japan), 2. Department of Agricultural Engineering, Bangabandhu Sheikh Mujubur Rahman Agricultural University,Salna,Gazipur-1706.(Bangladesh), 3. Senior Researcher, Hyogo Prefectural Agriculture, Forestry and Fisheries Technology Research Center, Addo City, Hyogo Prefecture ,671-3441.(Japan)）

11:00 AM - 11:15 AM

[4-1015-D-05] Quantification of Tofu microstructure by image analysis

*CHIANG WEN-HSIN[1], Yoshito SAITO[1], Kohei OGATA[1], Tetsuhito SUZUKI[1], Naoshi KONDO[1] （1. Graduate School of Agriculture, Kyoto University(Japan)）

11:15 AM - 11:30 AM

[4-1015-D-06] Processing of Green Tea Paste by Micro Wet Milling and Quality Evaluation During Storage

*Md Zohurul Islam[1], Yutaka Kitamura[1], Mito Kokawa[1], Shinya Fujii[2], Hisayuki Nakayama[2] （1. Graduate School of Life and Environmental Sciences, University of Tsukuba, Ibaraki, Tsukuba-shi, Japan(Japan), 2. Nagasaki Agricultural and Forestry Technical Development Center, Nagasaki, Japan(Japan)）

11:30 AM - 11:45 AM

[4-1015-D-07] Quality Changes During Ripening of Mango (*Mangifera indica* L. ‘Nam Dok Mai’) under Different Temperature Conditions

*Eriko Yasunaga[1], Kohei Nakano[2], Busarakorn Mahayothee[3], Pramote Khuwijitjaru[3], Shinji Fukuda[4], Wolfram Spreer[5] （1. The University of Tokyo(Japan), 2. Gifu University(Japan), 3. Silpakorn University(Thailand), 4. Tokyo University of Agriculture and Technology(Japan), 5. Hohenheim University(Germany)）

11:45 AM - 12:00 PM

10:15 AM - 10:30 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room D)

[4-1015-D-01] Effects of Operational Conditions of Internal Combustion Furnace on rice husk Biochar and vinegar

*WEI-PUO KUO[1], YUTAKA KITAMURA[2], Yoshiyuki HARA[4], CHING-CHEN HSIEH[3], YI-HUNG LIN[3], CHEN-PIN CHEN[1] (1. Taiwan Agricultural Machinery and Biomechatromics Engineering Technology Development Association(Taiwan), 2. University of Tsukuba(Japan), 3. National Pingtung University of Science and Technology(Taiwan), 4. Hokkaido Agricultural Experiment Station(Japan))
Keywords: Rice husk, ICF Internal Combustion Furnace, Bio vinegar , Biochar, Sustainable Agriculture

Traditionally, it is very difficult to make rice hulls useful industrial or agricultural products. Most of them are used as the bedding for cattle farms or even burned as fertilizers. The composition of rice hulls is actually very unique in nature. It contains approximately 20% opaline silica in combination with a large amount of the phenyl propanoid structural polymers called lignin. This abundant agricultural waste has all of the properties qualified with excellent insulating materials. Recent researches revealed that rice hulls are not very flammable and are highly resistant to moisture penetration and fungal decomposition. Moreover, rice hulls do not transfer heat very well, smell or emit gases, and are not corrosive with respect to aluminum, copper or steel. In the natural form, the rice hull is classified as a Class A or Class I insulation material, and therefore, can be used very economically to insulate the wall, floor and roof cavities of a house.
In order to extent the application of rice hulls, an innovative Internal Combustion Furnace (ICF) was developed to produce two type of bio-products, such as rice husk biochar and rice husk vinegar, respectively. Rice husk was produced by dried rice hulls that is firstly anaerobic smoked in ICB. Carbonized rice husks or biochar and rice husk vinegar are produced at the same time, which can be recycled in farmland. This approach made significant contributions to nature's sustainable management of agricultural wastes.
In Taiwan. However, the optimal conditions for operating ICF, including temperature, time, and composition of raw materials, are necessary to be determined, so that the good quality and quantity of biochar and biovinegar can be maintained. In this experiment, the ratio of gray matter and carbon was measured to understand carbonization rate as well as the quality of biochar and biovinegar with varying the opening of damper or the furnace air intake. In particular, 9 experiments on burning carbonized rice husks were conducted at 5, 7.5 and 10 mm opening of the damper. Along with the experimental chart, we could figure out that chimney temperature (front and end) and combustor temperature (top and bottom) have a positive relation to the opening width. The amount of biovinegar with cooling water is more than the one without cooling water. The wider the damper got, the higher the ratio of carbon and dust or ash volume.

10:30 AM - 10:45 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room D)

[4-1015-D-02] Assessment of Red Tomato Freshness Using Ultraviolet-induced Fluorescence Image

*Keiji Konagaya[1], Dimas Firmanda Al Riza[1], Minori Yoneda[1], Sen Nie[1], Takuya Hirata[2], Noriko Takahashi[2], Makoto Kuramoto[2], Tetsuhito Suzuki[1], Naoshi Kondo[1] (1. Kyoto Univ.(Japan), 2. Ehime Univ.(Japan))
Keywords: tomato (*Solanum lycopersicum*), storage, fluorescence image, color image, RGB values

A tomato (*Solanum lycopersicum*) is harvested with a yellow, pink or red color, although it turns red when it reaches to a consumer. The red tomato is better in taste. Thus, the agriculture near an urban area make use of the red tomato at the harvest in some countries including Japan. However, the color of red tomato does

not change. Thus, it is difficult to distinguish a degraded tomato from a fresh one. This is a limitation of a color for an indicator of tomato freshness. In contrast, ultraviolet (UV)-induced fluorescence provides another color information of tomatoes. In this study, we investigated a potential of tomato fluorescence to monitor the tomato freshness during the storage. Tomatoes (cultivar: Momotaro) were harvested on June 19th, 2018 at greenhouse in Ehime University with a red color. The total of 50 tomatoes were stored at 4 and 25˚ C for 8 d. A halogen lamp and UV light emitting diode (LED, 365 nm) were used for light sources of color and fluorescence images, respectively. A high-resolution CMOS camera EOS Kiss x7 (Canon Inc., Japan) with parameters set as ISO 100, F-6.3 and shutter exposure 1/25 s (for color images) and 4 s (for fluorescence image) was used. The color and fluorescence images were captured during the storage. The efficacies of these techniques were discussed in terms of the possible evaluation period and the sensitive color channel. In the color image, tomato color changed from a red to a deeper red, while in the fluorescence image the color changed from a blue to a blue-white gradually. At 4˚ C, the changes in both colors were relatively small compared with 25˚ C storage. To quantify the chromaticity, RGB values of each image was calculated and then expressed as its ratio (such as R/(R+G+B)) followed by the normalization using its initial mean value. In the color image, the R and G ratio changed rapidly within the initial 2 or 4 d, while in the fluorescence image, the G ratio changed up to 8 d. The reasons of these changes are also important for the application of this technique to the field. The origin of the color image was assigned to the lycopene synthesis, as shown in our extracts. In contrast, the excitation-emission matrix (EEM) of tomato pericarp suggested the origin of fluorescence images. EEM exhibited no fluorescence peak of lycopene in visible region. This was reasonable, since carotenoid is known to be week in the fluorescence. There also existed no peak of chlorophyll. This is also reasonable, since in the past studies, it is known that there are few chlorophylls in red tomatoes near the detection limit of high-performance liquid chromatography (HPLC). Hence, the possible origin of fluorescence image was some phenolics including flavonoid since phenolics are abundant in the tomato skin. Overall, the fluorescence image (the G ratio) was effective to monitor the tomato freshness for entire 8 d, while the color image (the R and G ratio) was effective only for the initial 2 or 4 d. As the most transportation and storage process happen in a cold chain with an ambient air, this study would help the development of monitoring system after the harvest before consumption.

10:45 AM - 11:00 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room D)

[4-1015-D-03] Thermal oxidation stability assessment of extra virgin olive oil using fluorescence and transmittance imaging system

*Vincent Rotich[1], Dimas Firmanda Al Riza[1], Ferruccio Giametta[2], Tetsuhito Suzuki[1], Yuichi Ogawa[1], Naoshi Kondo[1] （1. Kyoto University(Japan), 2. University of Molise(Italy)）

Keywords: Thermal stability, Extra virgin olive oil, Fluorescence, Transmittance, Imaging system

Extra virgin olive oil is a high-quality product with profound health benefits but is susceptible to degradation due to oxidation. Environmental conditions such as temperature, oxygen, and light promote the oxidation process. Thermal oxidation stability is of primary concern regarding food quality and safety. The ability to resist oxidation guarantees both nutritional and economic value. In this study, the thermal oxidation stability of four mono-cultivars of extra virgin olive oil from different regions of Italy was studied. The samples were placed under thermal treatment at 120˚ C and measurements done at equal time intervals for 180 minutes. To develop a simplified imaging system, the fluorescence characteristics of samples at the different duration of thermal exposure was measured using front-face fluorescence spectroscopy. An imaging system based on

fluorescence and transmittance was developed to assess the changes that occur due to thermal exposure. The quality indices including; Peroxide value, acidity, K232, and K270 were measured following IOC (International Olive Council) standard procedures. Image processing of both colour and fluorescence images was done to ascertain the cultivar response to the thermal treatment. The fluorescence peak regions for polyphenols, oxidation products, and chlorophyll were monitored, and a comparison made between the different cultivars. New fluorescence peaks were formed at emission wavelengths 435nm and 465nm, and 570nm, suspected to be products of oxidation and hydrolysis respectively. The cultivars with a high concentration of polyphenols showed greater resistance to the formation of oxidation products. The b* component of CIE L*a*b* colour space was identified to monitor the colour changes due to thermal exposure and to ascertain the thermal stability of different cultivars of extra virgin olive oil.

11:00 AM - 11:15 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room D)

[4-1015-D-04] Chalkiness Index of Sake Rice “Yamada Nishiki” Using Ultraviolet-Near-Infrared Transmission

*Khokan Kumar Saha[1,2], Firmanda Al Riza Dimas[1], Yuichi Ogawa[1], Tetsuhito Suzuki[1], Naoshi Kondo[1], Takuma Sugimoto[3] (1. Lab of Bio-sensing Engineering,Graduate School of Agriculture, Kyoto University, Kitashirakawa-Oiwakecho,Sakyo-ku ,606-8502.(Japan), 2. Department of Agricultural Engineering, Bangabandhu Sheikh Mujubur Rahman Agricultural University,Salna,Gazipur-1706.(Bangladesh), 3. Senior Researcher, Hyogo Prefectural Agriculture, Forestry and Fisheries Technology Research Center, Addo City, Hyogo Prefecture ,671-3441.(Japan))

Keywords: White core, Transmittance, Chalky thickness , Sake rice

White core refers to the opaque area in the kernel which is an important consideration for grading the raw material (sake rice) in the brewing industry. There is a relation between white core level and polishing ratio for sake rice to make premium quality sake. Currently, the evaluation of white core level in grains of sake rice is performed by the internal chalky thickness which is a destructive method. The aim of this research is the grading of sake rice chalkiness in non-destructively. Non-white core and white core [light, medium] and chalky rice, cultivar “Yamada Nishiki”, were used for this experiment. In this research, the transmission optical property in the ultraviolet-near-infrared (UV-NIR) region of rice was measured in order to characterize the suitable wavelength region in sake rice. The transmission optical property was measured by Jasco V-670 spectrophotometer equipped with an integrating sphere (ISH-723). The thickness of the chalky part was measured destructively. The evaluation of transmission optical property was done by image processing techniques. The images acquired by transmission mode of 4 types of intact sake rice kernel by using ring UV LEDs, Blue LEDs, Green LEDs, Red LEDs, and NIR LEDs in which the peak wavelength of the LEDs was 365nm, 465nm,525nm,630nm, and 830 nm respectively. The rice samples were more penetrated by light in the NIR region. The result indicates that there is more contrast between white core and non-white core rice in NIR image and followed by the red, green, blue and UV region images. Therefore, the wavelength region in NIR showed better discrimination between white core and non-white core sake rice. Finally, four images features; the ratio of the area (opaque area to full area), transmittance gray level intensity, the ratio of axis length in opaque (minor axis length to major axis length of opaque) and distance of centroid (opaque and full) were extracted from NIR transmittance images. The proposed chalkiness index (ratio of chalky thickness to whole kernel thickness) was inversely correlated with NIR transmittance image gray level intensity. The classification accuracy of the white core and chalky rice was 94.34% by support vector machine (SVM). Therefore, these results can be used to developed machine vision-based white core detection of sake rice.

11:15 AM - 11:30 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room D)

[4-1015-D-05] Quantification of Tofu microstructure by image analysis

*CHIANG WEN-HSIN[1], Yoshito SAITO[1], Kohei OGATA[1], Tetsuhito SUZUKI[1], Naoshi KONDO[1] (1. Graduate School of Agriculture, Kyoto University(Japan))

Keywords: Tofu, microstructure quantification, image analysis, stiffness

Coagulation of soymilk, a complicated process in the production of tofu, is a critical step that complex factors, such as coagulant concentration, cooking temperature, and coagulant type, involved may affect the physical properties of tofu. The microstructure of bio-aggregates is fundamental to their physical properties (Lawrence *et al.,*2017). Until today, however, there are few researches on the relationship between tofu physical property and microstructure and only qualitative descriptions of tofu curd have been recorded. The aim of this study was to quantitatively and objectively evaluate tofu microstructure using image analysis and verify the relationship between tofu microstructure and stiffness while varying coagulant concentration. The tofu samples were made with varying coagulant concentration. These samples were then photographed using SEM for imaging analysis. In this research, Harilick textural features were calculated to quantify the microstructure of tofu curd and selected by Principal Component Analysis (PCA). 3 geometric parameters (number of holes per area, size of holes(area), and porosity) and selected Haralick textural features were finally correlated with Young’ s modulus to verify the relationship between tofu microstructure and stiffness. The proposed methods, Haralick texture analysis and microstructure quantification, have potential discrimination application in tofu SEM image. As coagulant concentration increased, the number of holes and sum average feature also increased, however porosity decreased. From these findings, it was observed that the number of holes, porosity and sum average feature are candidate features for tofu microstructure quantification of SEM images. Moreover, correlations between stiffness with porosity and sum average feature were negative and positive respectively. Although the two tendencies were observed, in the future, more samples with varying concentration are necessary to improve the results.

11:30 AM - 11:45 AM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room D)

[4-1015-D-06] Processing of Green Tea Paste by Micro Wet Milling and Quality Evaluation During Storage

*Md Zohurul Islam[1], Yutaka Kitamura[1], Mito Kokawa[1], Shinya Fujii[2], Hisayuki Nakayama[2] (1. Graduate School of Life and Environmental Sciences, University of Tsukuba, Ibaraki, Tsukuba-shi, Japan(Japan), 2. Nagasaki Agricultural and Forestry Technical Development Center, Nagasaki, Japan(Japan))

Keywords: Green Tea Paste, MWM, Color, Antioxidants, Storage study, Kinetic model

Green tea is a delicious variety of tea that is made from the *Camellia sinensis* plant. It is a non-fermented tea, thus contain higher amounts of phytochemicals, alkaloids, polyphenols including EGCG compared with black tea and oolong tea. In this regard there is increasing interest in its health benefits has led to the inclusion of green tea in the processing of value-added products with functional properties. But there are challenges to add green teas into the process product due to the higher particle sizes and insolubility in cold water. Therefore, the aim of the present study was to develop green tea paste by micro wet milling system with minimum particle sizes which lead to increase solubility and enhance bioactive compounds. In the present

study, three varieties of green tea samples Yabukita (shaded) Yabukita (non-shaded) and Hoji cha were collected from Nagasaki, Japan. The green tea paste was produced by MWM. The wet milling conditions were set by varying the green tea to water ratio (10:90; 15:85; and 20:80 w/w), feeding rate (15 mL/min to 25 mL/min) and constant rotational speed of 50 rpm for the preparation of green tea paste. The optimum milling conditions were determined based on achieving minimum particle sizes. Feeding rate 20 mL/min, green tea to water ratio of 20:80 w/w, and rotational speed 50 rpm can able to produce paste with smaller average particle sizes of 58.64±2.31 µm with better color (in terms of greenness and chroma value) and nutrition properties (i.e. ascorbic acid, polyphenol, and antioxidants). To evaluate the shelf life and storage stability, three kinds of green tea paste were stored at 20 ˚ C, 4 ˚ C, -18 ˚ C and -60 ˚ C with vacuum packing for 4 weeks. Temperature and storage time negatively influenced the stability of ascorbic acid, color, and antioxidant activity during storage. A kinetic study of the green tea paste was conducted to quantify the losses occurring in ascorbic acid, antioxidant activity and changes in the color of the green tea paste. The study revealed that the logistic model can predict the variation in ascorbic acid and antioxidant activity with higher R^2 = 0.98 value. However, first-order kinetic models were found suitable to predict the changes occurring in ascorbic acid, antioxidant activity and color properties (L, a, b, chroma). Whereas the total color changes (Δ E) showed a good fit with zero order kinetic models (R^2 = 0.98). So we concluded that we can preserve the green tea paste at a lower temperature by keeping minimum losses of color and antioxidant properties. Before commercialization, a sensory and microbial study needs to be carried out in the future.

11:45 AM - 12:00 PM (Wed. Sep 4, 2019 10:15 AM - 12:00 PM Room D)

[4-1015-D-07] Quality Changes During Ripening of Mango (*Mangifera indica* L. ‘Nam Dok Mai’) under Different Temperature Conditions

*Eriko Yasunaga[1], Kohei Nakano[2], Busarakorn Mahayothee[3], Pramote Khuwijitjaru[3], Shinji Fukuda[4], Wolfram Spreer[5] (1. The University of Tokyo(Japan), 2. Gifu University(Japan), 3. Silpakorn University(Thailand), 4. Tokyo University of Agriculture and Technology(Japan), 5. Hohenheim University(Germany))
Keywords: accumulated respiration, climacteric rise, chilling injury, sucrose contents, hardness

The purpose of this study was to clarify the influence of storage temperature on the relationship between the accumulated respiration and the quality change during the ripening of unripe (green) mango fruits (*Mangifera indica* L. ‘Nam Dok Mai’). Unripe mango fruits were placed in an incubator at 10 ˚ C and 25 ˚ C to measure respiration rate and quality changes for 6 days. Postharvest ripening of unripe mango fruits was observed as changes in fruit firmness, peel color, brix, acidity, citric acid content, and sugar content under the storage conditions. The respiration rate of mango fruits stored at 25 ˚ C gradually increased from day 2 with a peak of climacteric rise on day 5, while climacteric rise for fruits stored at 10 ˚ C was not observed. It was confirmed from the respiration rate that post-ripening was not promoted at 10 ˚ C. The hardness, peel color, sucrose content and citric acid content of the fruit stored at 25 ˚ C decreased rapidly after day 2, while there was almost no change in the fruit stored at 10 ˚ C for 6 days. The accumulated respiration the fruit stored at 25 ˚ C for two days was equivalent to the fruit stored at 10 ˚ C for 6 days, both showing the same value in all quality indicators measured in this study.

Oral Session | Postharvest/Food Technology and Process Engineering

[4-1330-A] Postharvest/Food Technology and Process Engineering (2)

Chair:Olaniyi A. Fawole(Stellenbosch University, South Africa), nutthachai pongprasert(King Mongkut's University of Technology Thonburi, Thailand)

Wed. Sep 4, 2019 1:30 PM - 3:30 PM Hall A (Main Hall)

[4-1330-A-01] Edible Coatings Control Shrivel and Maintain Quality of Nectarines during Simulated Export Conditions

Shannon Riva[2], *Olaniyi Amos Fawole[1], Umezuruike Linus Opara[1,2] (1. Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Department of Food Science, Stellenbosch University(South Africa), 2. Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Department of Horticultural Science, Stellenbosch University(South Africa))

1:30 PM - 1:45 PM

[4-1330-A-02] Development and Characterization of Chitosan Film Incorporated with Cashew (*Anacardium Occidentale*) Leaf Extracts

*moooksupang - Liangpanth[1,2,3] (1. Mae Fah Luang University(Thailand), 2. Thomas Karbowiak(France), 3. Wirongrong Tongdeesoontorn(Thailand))

1:45 PM - 2:00 PM

[4-1330-A-03] Green Synthesis of Zinc Oxide Nanoparticles from Asiatic Pennywort (*Centella asiatica* L.) and Its Effect on the Rice Starch-Gelatin Composite Film

*Wantida Homthawornchoo[1,2], Suttiporn Pinijsuwan[1,2], Saroat Rawdkuen[1,2] (1. School of Agro-Industry, Mae Fah Luang University(Thailand), 2. Innovative Food Packaging and Biomaterials Unit (IFP), Mae Fah Luang University,(Thailand))

2:00 PM - 2:15 PM

[4-1330-A-04] Combination of high pressure processing and heat treatment on quality and antioxidant activity of fresh-cut persimmon

Paweena Jarungjitaree[1], Matchima Naradisorn1[1,2], Daisuke Hamanaka [3], *Sutthiwal Setha [1,2] (1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai, 57100, Thailand(Thailand), 2. Research Group of Postharvest Technology, Mae Fah Luang University, Chiang Rai, 57100, Thailand(Thailand), 3. Faculty of Agriculture, Kagoshima University, Kagoshima, 8900065, Japan(Japan))

2:15 PM - 2:30 PM

[4-1330-A-05] Postharvest Ethylene Application Influences Biochemical Quality of Pummelo Fruit Under Low Temperature Storage

*Paemika Promkaew[1], Varit Srilaong[2], Satoru Kondo[1] (1. Graduate School of Horticulture, Chiba University(Japan), 2. Division of Postharvest Technology, School of Bioresources and Technology, King Mongkut's University of Technology Thonburi (Bangkhuntien)(Thailand))

2:30 PM - 2:45 PM

[4-1330-A-06] Quality Characteristics of Thai Coconut Candy as Affected by Rice Starch-Based Film Enriched with Dragon Fruit Peel Extract

*Wantida Homthawornchoo[1,3], Nur Fairuza Syahira Mohamad Hakimi[2,1], Saroat Rawdkuen

[1,3] （1. Food Science and Technology Program, Mae Fah Luang University(Thailand), 2. Food Sciences and Technology Program, Universiti Teknologi MARA(Malaysia), 3. Innovative Food Packaging and Biomaterials Unit (IFP), Mae Fah Luang University(Thailand)）

2:45 PM - 3:00 PM

[4-1330-A-07] Antifungal Packaging for Prolonging Shelf Life of Table Grapes

*SIRIPORN LUESUWAN[1] （1. MAE FAH LUANG UNIVERSITY(Thailand)）

3:00 PM - 3:15 PM

1:30 PM - 1:45 PM (Wed. Sep 4, 2019 1:30 PM - 3:30 PM Hall A)

[4-1330-A-01] Edible Coatings Control Shrivel and Maintain Quality of Nectarines during Simulated Export Conditions

Shannon Riva[2], *Olaniyi Amos Fawole[1], Umezuruike Linus Opara[1,2] (1. Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Department of Food Science, Stellenbosch University(South Africa), 2. Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Department of Horticultural Science, Stellenbosch University(South Africa))

Keywords: Weight loss, 'August Red', Shrivel, Postharvest, Respiration rate

Nectarines are considered as one of the most important stone fruits of temperate origin. The fruit' s perishable nature, however, limits its commercial success; fruit is often exposed to very long handling chains during export. Edible coatings have shown great potential in maintaining quality and extending shelf life of fresh produce, and thus their application to nectarines is worth investigating as a green postharvest solution. Nectarines ('August Red') were treated with alginate (2%), chitosan (1.5%), gellan gum (0.5%) and gum arabic (2%) coatings and stored at -0.5 ± 1 ° C, 80 ± 5% RH for 35 days and then at 21 ± 1 ° C, 95 ± 5% RH for 20 days, simulating the cold storage shipment period and commercial shelf life period, respectively. Fruit were assessed at intervals for weight loss, fruit firmness, and colour changes, as well as respiration rates and ethylene evolution. Physiological disorders such as shrivel occurrence were assessed, as well as decay. The investigated edible coatings showed different effects, with gum arabic having the most effective performance on the plums. Fruit coated with gum arabic had the least weight loss while the highest weight loss was observed in uncoated fruit. In addition, the coating prolonged storage life by delaying fruit ripening and decreasing respiration rate and ethylene production. Furthermore, shrivel incidence was significantly ($p<0.05$) lower in fruit coated with gum arabic (2%) compared to the uncoated fruit (50%). Overall, the results suggested that gum arabic coating of nectarines was most effective to extend the storage life of nectarines ('August Red') and could be investigated further for commercial application.

1:45 PM - 2:00 PM (Wed. Sep 4, 2019 1:30 PM - 3:30 PM Hall A)

[4-1330-A-02] Development and Characterization of Chitosan Film Incorporated with Cashew (*Anacardium Occidentale*) Leaf Extracts

*moooksupang - Liangpanth[1,2,3] (1. Mae Fah Luang University(Thailand), 2. Thomas Karbowiak(France), 3. Wirongrong Tongdeesoontorn(Thailand))

Keywords: Cashew leaf extract, Antifungal property, Chitosan film

Chitosan is a material gotten from natural which is a non-toxic, biodegradable, biocompatible substance which contains antimicrobial and antioxidant properties. Normally, chitosan can be dissolved in acid affect the viscous solution that is suitable for making a film. Many studies reported that chitosan film combined with plant extracts showed the synergistic effect to antimicrobial properties. The previous studied found that cashew leaf extracts showed the biological properties such as antioxidant, antimicrobial, analgesic and anti-inflammatory. This research aimed to study the antimicrobial activities of cashew leaf extracted with water and 70% ethanol, and to study properties of chitosan film incorporated with cashew leaf extract. The result showed that ten percent of ethanolic and aqueous extracts could inhibit the growth of *Aspergillus niger*. An

ethanolic extract (CLE) had lower of minimal inhibitory concentration (MIC = 6.25 µg/100µl) than those of aqueous extract (CLAq) (MIC = 12.5 µg/100µl) but showed the same minimal fungal concentration (MFC =25 µg/100µl). For film properties, film solutions were prepared as (i) 2% chitosan, (ii) 2% chitosan + 5% CLE (w/v), (iii) 2% chitosan + 5% CLAq (w/v). All the films were determined color, thickness, barrier properties (WVTR, WVP, OTR) and antifungal activities. The highest values of thickness was obtained by chitosan combined with 5% CLE followed by chitosan mixed with 5% CLAq and chitosan film (control). Moreover, chitosan mixed with 5% CLE also gave lower WVTR and WVP than the other films. Furthermore, only chitosan combined with 5% CLE presented the antifungal property against the growth of *A. niger*. The chitosan film combined with cashew leaf extract could be a new alternative way of natural antifungal package which can be used in food and agricultural produce.

Oral Session | Postharvest/Food Technology and Process Engineering
[4-1330-A] Postharvest/Food Technology and Process Engineering (2)
Wed. Sep 4, 2019 1:30 PM - 3:30 PM Hall A (Main Hall)

[4-1330-A-03] Green Synthesis of Zinc Oxide Nanoparticles from Asiatic Pennywort (*Centella asiatica* L.) and Its Effect on the Rice Starch-Gelatin Composite Film

*Wantida Homthawornchoo[1,2], Suttiporn Pinijsuwan[1,2], Saroat Rawdkuen[1,2] (1. School of Agro-Industry, Mae Fah Luang University(Thailand), 2. Innovative Food Packaging and Biomaterials Unit (IFP), Mae Fah Luang University,(Thailand))

Keywords: Centella asiatica (L.), , Zinc oxide nanoparticles, Gelatin, Rice starch, Antimicrobial activity

Asiatic pennywort (*Centella asiatica* L.) is a plant that is abundantly available in Thailand. The *Centella asiatica* leaf extract (CAE) is known to possess antioxidant and antimicrobial properties as it contains polyphenols. This allows CAE to act as a reducing agents for a green synthesis of zinc oxide nanoparticles (ZnONPs). The ZnONPs provides a good antimicrobial activity, especially to bio-based packaging films. Therefore, in the objectives of this study were *(i)* to synthesize the ZnONPs using the CAE and *(ii)* to investigate the effects of the ZnONPs incorporation on the physicochemical, thermal, and antimicrobial properties of the rice starch-gelatin composite film. Briefly, ZnONPs were synthesis through the green method using CAE. The shape and the size of the prepared ZnONPs were found to be the rod shape of 100-300 nm in length. The ZnONPs were then added into the rice starch-gelatin composite film at different concentrations (i.e., 0, 0.5, 1, 2, and 3%, w/v). As the ZnONPs increased, the thickness of the developed film with ZnONPs addition were found to increase (Approx. 50-70 mm). The tensile strength (TS) were also increased from 3.49 to 4.63 MPa as well as the increasing of the water vapor permeability. The thermal stability of the developed film was also increased. However, the addition of ZnONPs reduced the elongation at break (EAB) (92.20-37.68%) and the film solubility (67.84 - 30.36%). Furthermore, ZnONPs also altered the color, appearance, transmission, and transparency properties of the prepared films with the crystalline structure presented as confirmed by X-ray diffraction (XRD) analysis. The antimicrobial activity of the rice starch-gelatin film enriched with ZnONPs against Gram-positive bacteria (*S. aureus* and *B. cereus*), Gram-negative bacteria (*E. coli* and *S.* Typhimurium), and fungal (*A. niger* and *C. alatae*) by disc diffusion method were found to be higher as the ZnONPs concentration increased while the rice starch-gelatin film without ZnONPs did not show the inhibition zone. Thus, the developed rice starch-gelatin film with ZnONPs could potentially be used as an antimicrobial packaging film.

Green Synthesis of Zinc Oxide Nanoparticles from Asiatic Pennywort (*Centella asiatica* L.) and Its Effect on the Rice Starch-Gelatin Composite Film

Wantida Homthawornchoo[1, 2, *], Suttiporn Pinijsuwan[1, 2], Saroat Rawdkuen[1, 2]

[1]Food Science and Technology Program, School of Agro-Industry, Mae Fah Luang University, Thailand
[2]Innovative Food Packaging and Biomaterials Unit (IFP), Mae Fah Luang University, Thailand

*Corresponding author: wantida.hom@mfu.ac.th

ABSTRACT

Asiatic pennywort (*Centella asiatica* L.) is a plant that is abundantly available in Thailand. The *Centella asiatica* leaf extract (CAE) is known to possess antioxidant and antimicrobial properties as it contains polyphenols. This allows CAE to act as a reducing agents for a green synthesis of zinc oxide nanoparticles (ZnONPs). The ZnONPs provides a good antimicrobial activity, especially to bio-based packaging films. Therefore, in the objectives of this study were *(i)* to synthesize the ZnONPs using the CAE and *(ii)* to investigate the effects of the ZnONPs incorporation on the physicochemical, thermal, and antimicrobial properties of the rice starch-gelatin composite film. Briefly, ZnONPs were synthesis through the green method using CAE. The shape and the size of the prepared ZnONPs were found to be the rod shape of 100-300 nm in length. The ZnONPs were then added into the rice starch-gelatin composite film at different concentrations (i.e., 0, 0.5, 1, 2, and 3%, w/v). As the ZnONPs increased, the thickness of the developed film with ZnONPs addition were found to increase (Approx. 50-70 μm). The tensile strength (TS) were also increased from 3.49 to 4.63 MPa as well as the increasing of the water vapor permeability. The thermal stability of the developed film was also increased. However, the addition of ZnONPs reduced the elongation at break (EAB) (92.20-37.68%) and the film solubility (67.84 - 30.36%). Furthermore, ZnONPs also altered the color, appearance, transmission, and transparency properties of the prepared films with the crystalline structure presented as confirmed by X-ray diffraction (XRD) analysis. The antimicrobial activity of the rice starch-gelatin film enriched with ZnONPs against Gram-positive bacteria (*S. aureus* and *B. cereus*), Gram-negative bacteria (*E. coli* and *S.* Typhimurium), and fungal (*A. niger* and *C. alatae*) by disc diffusion method were found to be higher as the ZnONPs concentration increased while the rice starch-gelatin film without ZnONPs did not show the inhibition zone. Thus, the developed rice starch-gelatin film with ZnONPs could potentially be used as an antimicrobial packaging film.

Keywords: *Centella asiatica* (L.), Zinc oxide nanoparticles, Gelatin, Rice starch, Antimicrobial activity

2:15 PM - 2:30 PM (Wed. Sep 4, 2019 1:30 PM - 3:30 PM Hall A)

[4-1330-A-04] Combination of high pressure processing and heat treatment on quality and antioxidant activity of fresh-cut persimmon

Paweena Jarungjitaree[1], Matchima Naradisorn1[1,2], Daisuke Hamanaka [3], *Sutthiwal Setha[1,2] (1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai, 57100, Thailand(Thailand), 2. Research Group of Postharvest Technology, Mae Fah Luang University, Chiang Rai, 57100, Thailand(Thailand), 3. Faculty of Agriculture, Kagoshima University, Kagoshima, 8900065, Japan(Japan))
Keywords: Antioxidant activity, Browning, Heat treatment, High pressure processing, Persimmon

The effect of high pressure processing (HPP) in combination with heat treatment on storage quality and antioxidant activity of fresh-cut persimmon were investigated. Flesh persimmon (*Diospyros kaki* L., cv. ‘Hiratanenashi’) were cut and treated by HPP at 80 MPa combined with heat treatment at 40˚C for 5, 10 and 15 minutes, non-treated was used as a control treatment. Then, they were stored at 5 ˚C for 8 days. The quality determinations were measured for respiration rate, weight loss, color, flesh firmness, total soluble solid, polyphenol oxidase activity (PPO), total phenolic content (TPC) and antioxidant activity by 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity and ferric reducing antioxidant power (FRAP) assays. The result showed that HPP-treated had significantly lower respiration rate and weight loss than the non-treated. During the period evaluated, *L**, *C** and flesh firmness were significantly lower in HPP-treated than the non-treated. PPO activity increased during storage however HPP-treated for 5 and 10 min could reduce the PPO activity when compared with other treatments. TPC, DPPH radical scavenging activity and FRAP activity decreased during storage but HPP-treated for 5 min maintained significantly higher values of TPC, DPPH and FRAP than the other treatments. HPP (80 MPa) combined with mild heat treatment (40˚C) for 5 min provides potentially beneficial maintained high antioxidant activity and reduced respiration rate, weight loss and PPO activity with only a slight translucency caused by high pressure in fresh-cut persimmon.

2:30 PM - 2:45 PM (Wed. Sep 4, 2019 1:30 PM - 3:30 PM Hall A)

[4-1330-A-05] Postharvest Ethylene Application Influences Biochemical Quality of Pummelo Fruit Under Low Temperature Storage

*Paemika Promkaew[1], Varit Srilaong[2], Satoru Kondo[1] (1. Graduate School of Horticulture, Chiba University(Japan), 2. Division of Postharvest Technology, School of Bioresources and Technology, King Mongkut's University of Technology Thonburi (Bangkhuntien)(Thailand))
Keywords: Ethylene, Pummelo, Low temperature

The effects of exogenous ethylene on the biochemical quality of 'Tumtim Siam' pummelo (*Citrus maxima* Burm.) fruit under low temperature were investigated. Fruit were treated with 10 µL L^{-1} ethylene for 12 hours at 25 ˚C and then stored at 10 ˚C for 40 d. Fruit treated with ethylene showed a remarkable ethylene production after 10 d and respiration rate at 20 d. The chlorophyll concentrations and hue angle value of peel and pulp were decreased by ethylene treatment compared to the untreated control. The carotenoid, phenolic and ascobic acid concentrations were significantly higher at 20 and 30 d in the ethylene treated-fruit than the untreated control. However, sugar concentrations were significantly higher at 20 and 30 d in the untreated control than the fruit treated with ethylene. Overall, ethylene had a significant effect on the

peel and pulp coloration and on the biochemiacl qualities in pulp of the fruit during storage at low temperature.

Oral Session | Postharvest/Food Technology and Process Engineering
[4-1330-A] Postharvest/Food Technology and Process Engineering (2)
Wed. Sep 4, 2019 1:30 PM - 3:30 PM Hall A (Main Hall)

[4-1330-A-06] Quality Characteristics of Thai Coconut Candy as Affected by Rice Starch-Based Film Enriched with Dragon Fruit Peel Extract

*Wantida Homthawornchoo[1,3], Nur Fairuza Syahira Mohamad Hakimi[2,1], Saroat Rawdkuen[1,3] (1. Food Science and Technology Program, Mae Fah Luang University(Thailand), 2. Food Sciences and Technology Program, Universiti Teknologi MARA(Malaysia), 3. Innovative Food Packaging and Biomaterials Unit (IFP), Mae Fah Luang University(Thailand))

Keywords: Rice starch-based film, Dragon fruit peel extract, Coconut milk candy, Lipid oxidation, Antioxidant

Thai coconut candy or *Kalamae*, a soft and luscious caramel candy, typically made from glutinous rice flour, palm sugar, and coconut milk. The Thai coconut candy short shelf life, due to lipid oxidation and starch retrogradation of the Thai coconut candy, has affected its quality and subsequently limited its market growth. In addition, the use of bio-based plastic instead of petroleum-based plastic packaging is now a good practice as the latter is harmful to the environment and sea life. So, the objectives of this study are *i)* to apply the starch-based (RS) film with dragon fruit peel extract (DPE) as a packaging of the Thai coconut candy and *ii)* to determine the quality attributes of the Thai coconut candy as affected by the RS-DPE film. The dragon fruit peel was extracted and freeze-dried to obtain the DPE powder. The rice starch-based film with DPE of 2 %w/w solid was prepared by the air-dried casting method. The thickness, color, appearance, water vapor permeability (WVP), total phenolic content (TPC), total betacyanin content (TBC), and DPPH scavenging activity (%DPPH) of the RS-DPE film were determined. Film appearance was smooth. The lightness (*L**) of the RS-DPE film, as compared to the RS film without DPE, was lowered but *a** and *b** values were increased toward redness and yellowness, respectively. The thickness of the film was also increased while the WVP was not altered. The RS-DPE film exhibited a significantly higher amount of TPC and TBC with the higher %DPPH than the RS film. The Thai coconut candies were wrapped in the RS-DPE films and kept in the control chamber at 25 ºC, 50% RH. The commercial polypropylene plastic was used as a control. The quality characteristics of the Thai coconut candy were assessed at day 1, 3, 5, 7, and 9, respectively. There was no significant difference ($p < 0.05$) in the a_w and moisture content (MC) of the candies packaged in both film treatments. As the storage time progressed, the aw and MC were reduced. The results were confirmed by the significant increase in hardness (N) and springiness (%) of the candies wrapped in both film types as time increased. However, hardness and springiness of the candies wrapped in the RS-DPE film were higher than that packed in the commercial film. The lipid oxidation expressed as Thiobarbituric acid reactive substance (TBARS) was increased in all treatments over time. However, the candies wrapped in RS-DPE film showed a significant lower in TBARS values. Thus, this could be implied that the RS-DPE film helps delay lipid oxidation in the candy but the water barrier needed to be improved in order to retain the soft and springy texture of the Thai coconut candy.

Quality Characteristics of Thai Coconut Candy as Affected by Rice Starch-Based Film Enriched with Dragon Fruit Peel Extract

Wantida Homthawornchoo[1, 3, *], Nur Fairuza Syahira Mohamad Hakimi[1, 2], Saroat Rawdkuen[1, 3]

[1] Food Science and Technology Program, School of Agro-Industry, Mae Fah Luang University, Thailand
[2]Food Sciences and Technology Program, School of Applied Science, Universiti Teknologi MARA, Malaysia
[3] Innovative Food Packaging and Biomaterials Unit (IFP), Mae Fah Luang University, Thailand

*Corresponding author: wantida.hom@mfu.ac.th

ABSTRACT

Thai coconut candy or *Kalamae*, a soft and luscious caramel candy, typically made from glutinous rice flour, palm sugar, and coconut milk. The Thai coconut candy short shelf life, due to lipid oxidation and starch retrogradation of the Thai coconut candy, has affected its quality and subsequently limited its market growth. In addition, the use of bio-based plastic instead of petroleum-based plastic packaging is now a good practice as the latter is harmful to the environment and sea life. So, the objectives of this study are *i)* to apply the starch-based (RS) film with dragon fruit peel extract (DPE) as a packaging of the Thai coconut candy and *ii)* to determine the quality attributes of the Thai coconut candy as affected by the RS-DPE film. The dragon fruit peel was extracted and freeze-dried to obtain the DPE powder. The rice starch-based film with DPE of 2 %w/w solid was prepared by the air-dried casting method. The thickness, color, appearance, water vapor permeability (WVP), total phenolic content (TPC), total betacyanin content (TBC), and DPPH scavenging activity (%DPPH) of the RS-DPE film were determined. Film appearance was smooth. The lightness (*L**) of the RS-DPE film, as compared to the RS film without DPE, was lowered but *a** and *b** values were increased toward redness and yellowness, respectively. The thickness of the film was also increased while the WVP was not altered. The RS-DPE film exhibited a significantly higher amount of TPC and TBC with the higher %DPPH than the RS film. The Thai coconut candies were wrapped in the RS-DPE films and kept in the control chamber at 25 ºC, 50% RH. The commercial polypropylene plastic was used as a control. The quality characteristics of the Thai coconut candy were assessed at day 1, 3, 5, 7, and 9, respectively. There was no significant difference ($p < 0.05$) in the a_w and moisture content (MC) of the candies packaged in both film treatments. As the storage time progressed, the aw and MC were reduced. The results were confirmed by the significant increase in hardness (N) and springiness (%) of the candies wrapped in both film types as time increased. However, hardness and springiness of the candies wrapped in the RS-DPE film were higher than that packed in the commercial film. The lipid oxidation expressed as Thiobarbituric acid reactive substance (TBARS) was increased in all treatments over time. However, the candies wrapped in RS-DPE film showed a significant lower in TBARS values. Thus, this could be implied that the RS-DPE film helps delay lipid oxidation in the candy but the water barrier needed to be improved in order to retain the soft and springy texture of the Thai coconut candy.

Keywords: Rice starch-based film, Dragon fruit peel extract, Coconut milk candy, Lipid oxidation, Antioxidant,

3:00 PM - 3:15 PM (Wed. Sep 4, 2019 1:30 PM - 3:30 PM Hall A)

[4-1330-A-07] Antifungal Packaging for Prolonging Shelf Life of Table Grapes

*SIRIPORN LUESUWAN[1] (1. MAE FAH LUANG UNIVERSITY(Thailand))

Keywords: Table grape, Essential oil, Antifungal packaging, Pathogenic fungi

The table grape (*Vitis vinifera* cv. 'Beauty seedless') becomes popular fruit in Thailand because it's seedless and sweet. The fungal decays in table grapes from *Botrytis cinerea*, *Penicillium* spp., *Aspergillus* spp., and *Rhizopus stolonifera* (soft-rot mold) are the main postharvest problems. To dissolve this problem for grapes exportation and distribution, many countries usually used sulfur dioxide (SO_2) fumigation in sachet and pad forms for inhibiting the fungal growth. However, the sulfur dioxide fumigation is not accepted in many countries because sulfur dioxide residues are potentially hazardous to human health. So, this research was studied about the new antifungal packaging for delaying the mold growth in table grapes by using natural essential oils. The concentration of essential oils (clove, cinnamon, thyme, peppermint, lemon, bergamot, ginger, spearmint, and lemongrass oils) at 0.5, 1, 2 and 5% (w/v) were used for screening the antifungal property against *Aspergillus* spp. by using the disk diffusion method, minimal inhibitory concentration (MIC) assay, minimal fungicidal concentration (MFC) assay, and determination of radial growth. The results showed that the clove, cinnamon and lemongrass oils could inhibit the growth of *Aspergillus* sp. In part of sensory evaluation by untrained panelists, they were accepted the odor of clove oil when apply in grape. So, clove oil was selected to use in application part. In application, grapes were packed into perforated polypropylene (PP) bag and devided into 5 groups; (i) without essential oil (control), (ii) with the essential oil in absorbent pad, (iii) with oriented polypropylene (OPP) film coated 7% polyvinyl alcohol mixed with essential oil, (iv)with OPP film coated 7% polyvinyl alcohol mixed with essential oil and 1% halloysite clay, and (v) commercial sulfer dioxide pad. The 300 grams of table grapes were packed and stored at 14 ° C, 75 %RH for 30 days. The weight loss and sensory evaluation of table grapes were determined every 3 days. The results showed that all of treatments could delay the growth of the pathogenic fungi except control. The OPP film coated 7% polyvinyl alcohol mixed with essential oil with and without halloysite clay could prolong shelf life of table grapes for 21 days. While control, perforated PP bag with the essential oil absorbent pad and commercial pad could prolong shelf life of table grape for 12, 15, and 18 days respectively.

Oral Session | Food Function/Nutrition

[4-1330-C] Functional/Wellness Foods &Nutrition (1)

Chair:Rosires Deliza(Embrapa Food Technology, Brazil)

Wed. Sep 4, 2019 1:30 PM - 2:30 PM Room C (3rd room)

[4-1330-C-01] The Influence of The Front-of-Pack Nutrition Labelling Schemes on Helping Healthier Food Choices by Consumer

*Rosires Deliza[1], Marcela Alcantara[2], Renata Vaqueiro Pereira[3], Gastón Ares[4] （1. Embrapa Food Technology(Brazil), 2. PDJ_CNPq/Embrapa Food Technology(Brazil), 3. Federal Rural University of Rio de Janeiro(Brazil), 4. Universidad de la Repú blica(Uruguay)）

1:30 PM - 1:45 PM

[4-1330-C-02] Colour and Chemical Composition of Karasumi-like Chinook salmon (*O. tshawytscha*) Roe Relevant to its Quality

*Senni Bunga[1,3], John Birch[1], Alan Carne[2], Alaa El-Din A Bekhit[1] （1. Departement of Food Science, University of Otago, New Zealand(New Zealand), 2. Department of Biochemistry, University of Otago, New Zealand(New Zealand), 3. Indonesia Endowment for Education (LPDP), Indonesia(Indonesia)）

1:45 PM - 2:00 PM

[4-1330-C-03] Effect of Inulin and *Carissa carandas* L. Supplementation on Physicochemical and Microbiological Properties of Frozen Yogurt

*Kamonwan Manowan[1,2], Ni-orn Chomsri[1,2] （1. Agricultural Technology Research Institute, Rajamangala University of Technology Lanna(Thailand), 2. Faculty of Sciences and Agricultural Technology, Rajamangala University of Technology Lanna(Thailand)）

2:00 PM - 2:15 PM

[4-1330-C-04] Utilization of Banana Agricultural Waste: Effects of Processing Conditions on Properties of Unripe Banana (*Musa Cavendish*) Pulp and Peel Flours

*Natthawuddhi Donlao[1,2], Asia Perin[1], Nasuha Bunyameen[1] （1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai, Thailand(Thailand), 2. Innovative Food Packaging and Biomaterials Unit (IFP), Mae Fah Luang University, Thailand(Thailand)）

2:15 PM - 2:30 PM

1:30 PM - 1:45 PM (Wed. Sep 4, 2019 1:30 PM - 2:30 PM Room C)

[4-1330-C-01] The Influence of The Front-of-Pack Nutrition Labelling Schemes on Helping Healthier Food Choices by Consumer

*Rosires Deliza[1], Marcela Alcantara[2], Renata Vaqueiro Pereira[3], Gastón Ares[4] （1. Embrapa Food Technology(Brazil), 2. PDJ_CNPq/Embrapa Food Technology(Brazil), 3. Federal Rural University of Rio de Janeiro(Brazil), 4. Universidad de la República(Uruguay)）

Keywords: Nutritional Warnings, Guideline Daily Amounts, Front-of-pack, Nutrition information, Food policy

Several new graphic designs for FOP nutrition labelling schemes are being developed worldwide; therefore, it is necessary to get an understanding of how they can influence the efficacy to facilitate the identification of nutrients associated with non-communicable diseases (NCDs). In the present work five nutritional warnings (black and red magnifier, black octagon, black triangle and red circle) that are being considered by Brazilian national authorities for implementing in the country, was compared with two of the most studied schemes (the guidelines daily amounts (GDA) and the traffic-light system) in terms of the perception of the product healthfulness by consumer. Fictitious labels of eight product categories frequently consumed in Brazil were considered: sponge cake, orange nectar, frozen lasagna, cereal bar, breakfast cereal, chocolate flavoured milk, yogurt and savoury snack. For this, an online survey with 1932 participants from the five regions of the country was carried out to evaluate their ability to use FOP nutrition labelling schemes to correctly identify the most healthful product in a set, as well as the high nutrient content in a product. In addition, the influence of FOP nutrition labelling schemes on perceived healthfulness was evaluated. Finally, consumers' perception of the schemes was gathered using an open-ended question. As expected, the GDA system showed the worst performance in terms of consumers' ability to identify the most healthful product in a set, and to identify products with high content of nutrients associated with NCDs. All the schemes that included textual or graphical interpretation aids showed a similar performance in improving consumers' ability to identify the most healthful product in a set of alternatives. However, the schemes based on familiar marks (the traffic-light, red circle, black octagon and black triangle) tended to show better performance compared to the red and black magnifier. Consumers showed a positive attitudes towards all the FOP nutrition labelling schemes, in line with previous studies that have highlighted that this public policy is strongly supported by citizens.

Oral Session | Food Function/Nutrition
[4-1330-C] Functional/Wellness Foods &Nutrition (1)
Wed. Sep 4, 2019 1:30 PM - 2:30 PM Room C (3rd room)

[4-1330-C-02] Colour and Chemical Composition of Karasumi-like Chinook salmon (*O. tshawytscha*) Roe Relevant to its Quality

*Senni Bunga[1,3], John Birch[1], Alan Carne[2], Alaa El-Din A Bekhit[1] (1. Departement of Food Science, University of Otago, New Zealand(New Zealand), 2. Department of Biochemistry, University of Otago, New Zealand(New Zealand), 3. Indonesia Endowment for Education (LPDP), Indonesia(Indonesia))

Keywords: Salmon roe, fermentation, colour, chemical composition

Salt drying of fish products has been used as a food preservation method since ancient times for the production of shelf-stable products. Chinook salmon (*O. tshawytscha*) fish roe was used to produce a salted-dried (Karasumi-like) roe product. The changes in colour properties and chemical compositions (proximate, pH, water activity, salt content, and acidity value) were studied over 20 days of salt-drying at 4˚C. Results showed that redness (a*) and yellowness (b*) were decreased gradually in value from 15.76 (at day 0) to 23.88 (at day 20) and from 24.88 (at day 0) to 3.44 (at day 20), respectively. Protein, lipid, ash, carbohydrate, salt content, and acidity value were higher ($P < 0.05$) after salted-drying. The water activity decreased from 0.98 (at day 0) to 0.82 (at day 20). The pH value fluctuated but was overall lower at the end of the processing step. This study highlighted the potential for converting raw or frozen salmon roe into a salted-dried product with added value, that may have beneficial effects on the nutritional and functional characteristics of the processed product.

2019 International Joint Conference
(Sapporo, JAPAN)

Colour and chemical composition of karasumi-like Chinook salmon (*O. tshawytscha*) Roe Relevant to its Quality

Senni Bunga[1,3*], John Birch[1], Alan Carne[2], Alaa El-Din A. Bekhit [1*],

[1]Department of Food Science, University of Otago, Dunedin, New Zealand

[2]Department of Biochemistry. University of Otago, Dunedin, New Zealand

[3]Indonesia Endowment for Education (LPDP), Indonesia

[*]*senni.bunga@postgrad.otago.ac.nz; aladin.bekhit@otago.ac.nz*

ABSTRACT

Salt drying of fish products has been used as a food preservation method since ancient times for the production of shelf-stable products. Chinook salmon (*O. tshawytscha*) fish roe was used to produce a salted-dried (Karasumi-like) roe product. The changes in colour properties and chemical compositions (proximate, pH, water activity, salt content, and acidity value) were studied over 20 days of salt-drying at 4°C. Results showed that redness (a*) and yellowness (b*) were decreased gradually in value from 24.49 (at day 0) to 5.18 (at day 20) and from 24.88 (at day 0) to 3.44 (at day 20), respectively. Protein, lipid, ash, carbohydrate, salt content, and acidity value were higher ($P < 0.05$) after salted-drying. The water activity decreased from 0.98 (at day 0) to 0.82 (at day 20). The pH value fluctuated, but was overall lower at the end of the processing step. This study highlighted the potential for converting raw or frozen salmon roe into a salted-dried product with added value that may have beneficial effects on the nutritional and functional characteristics of the processed product.

Key words: Salmon roe, fermentation, colour, chemical composition.

1. INTRODUCTION

Fish roe refers to the eggs of fish is widely consumed throughout the world as delicacy food. Chinook salmon (also known as king salmon) is the most important fish species farmed commercially in New Zealand. According to the New Zealand Aquaculture Industry (2018) reported harvests of approximately 8,000 metric tonnes of salmon and contributed more than 50% of the world's total king salmon supply. Large scale of the production leads to the utilization of the seafood by-product such as fish viscera, skin, head, and dark meat into new products such as food, nutraceuticals, pharmaceuticals and biotechnological applications (Kim & Mendis, 2006). The mature roe of Chinook salmon accounts for approximately 200 – 400 g of the total body weight and is considered a low-value by-product of the seafood industry.

Fish roe is rich in proteins, vitamins, minerals and ω-3 polyunsaturated fatty acids, but the content of these nutrients vary amongst fish species (Bledsoe et al., 2003). Information on the nutrition values of fresh or frozen fish roe has been reported widely in previous studies (Al-Sayed Mahmoud et al., 2008; Bah et al., 2016; Bekhit et al., 2009b; Heu et al., 2006; Intarasirisawat et al., 2011; Mol & Turan, 2008), however, little information about changes in their composition upon processing. Processing may play an important role to improve the nutritional values of fish roe or it may degrade some components that might be beneficial for human health. Fish roe products are available in different forms. Salted, salted-dried, and salted-fermented roe are some of the roe products that are consumed in certain countries. In Asian countries, such as in Japan, South Korea and Taiwan, fish roe from salmon, pollock, flying fish, and herring are salted and known as Ikura, Tarako, Tobiko, and Kazunuko, respectively. Mullet fish species have also been the main roe used in a salted-dried product, which is known in Japan as Karasumi; Avgotaraho in Greece; Bottargo in Italy and Batarekh in Egypt. Salted-fermented fish roe is known as Karashi-mentaiko in Japan and Jeotgal in Korea.

In this study, Chinook salmon roes were used to produce a salted-dried roe product similar to Karasumi. Changes in colour and physicochemical properties (roe skein size, proximate composition, pH, acidity, salt content, water activity, and weight loss) during the salted-drying process are important, as these factors will influence the quality and consumer's perceptions of the fish roe.

2. Material and Methods

2.1. Fish roe sample and processing

Fresh grade 1 Chinook salmon (*O. tshawytscha*) roe was used in this current study. The weight, length, and width of the roes were measured before processing. The surface of the roe skein then was covered with sea salt (7% of the wet weight). The drying process was conducted at 4°C in a chiller room for 20 days at fixed relative humidity of 80%. For optimal air circulation, stainless steel wire racks were

used for the drying of the roe samples. Sampling of the roe was carried out every 4 days. Each sampling day, three whole fish roes were randomly chosen for further analysis. Schematic overview of the roe processing is shown in Figure 1.

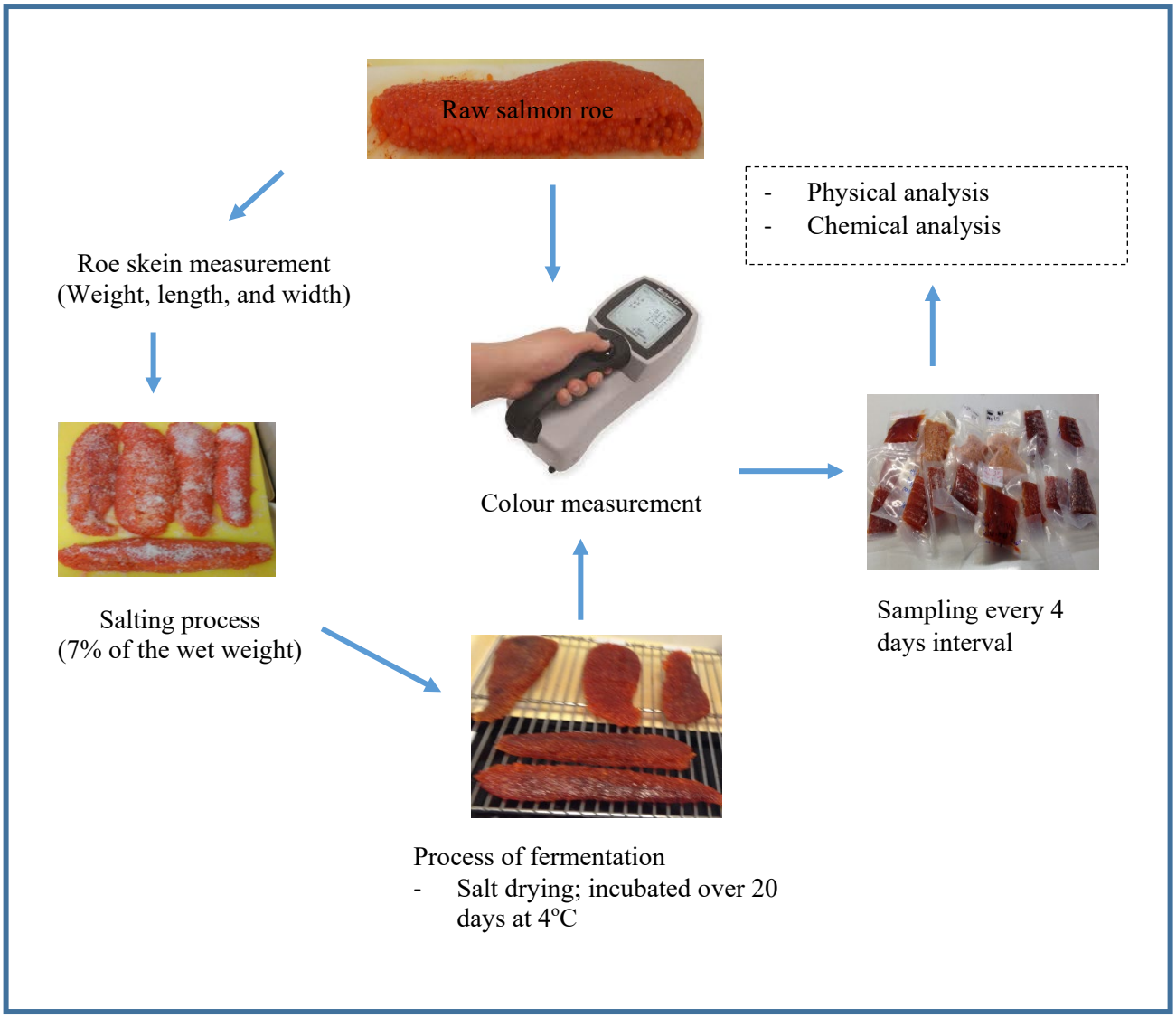

Figure 1. Diagram process of salted-dried product from raw roe salmon

2.2. Measurement of roe colour

The surface colour of the roes was measured using a Hunterlab MiniScan XE Plus Model 45/0-L (Hunter Associates Laboratory, Inc., Reston, VA, USA). The colour parameters L*, a*, b*, representing lightness, redness/greenness, and yellowness/ blueness, respectively, were measured at each sampling time. The instrument was calibrated using a standard black glass and a white tile according to the manufacture

guidelines. The sample was placed on the tray and covered with a polyvinyl film (AEP FilmPac, Ltd, New Zealand). Three replicate readings from random positions were taken from each skein and the average value was used for statistical analysis. Chroma and hue angle were calculated based on the following formula: C= [a*2 + b*2]1/2 and HA=tan-1 b*/a*, respectively.

2.3. Chemical analysis

2.3.1. Weight loss

Weight loss was measured every 4 days over the 20 days of salt-drying by removing the individual roe from the chiller room and were weighed using a Sartorius Type Universal U 4600 P scale.

2.3.2. Proximate compositions

Moisture content was determined using a gravimetric measurement of water content by freeze-drying of 5 g of roe sample until a constant weight was achieved. Total lipid was extracted from 3 g of freeze-dried roe using Soxhlet extraction according to the official method (AOAC, 1995). Crude protein content was determined by Kjeldahl-Nitrogen method (% N*6.25) according to the AOAC Official method 981.10 using a Tecator Kjeltec Auto Sampler System 1035 apparatus. Ash content was determined on 2 g of freeze-dried samples, carried out in duplicates from three separated skeins. Carbohydrate content was calculated by subtracting the sum of lipid, protein, ash and moisture content from the total weight of samples. Energy value was determined using the following formula as described by Falch et al. (2010):

[Energy (kcal/100g) = (lipid * 9) + (protein * 4) + ((carbohydrate * 4)]

2.3.3. pH and total acidity

The pH value was measured using a pH meter (HANNA Instrument model PH209, USA) in a 10 g of sample homogenized with 100 mL of deionized water at 6000 rpm using a homogenizer (IKA® T25 Digital Ultra Turrax, TLS, Total Lab-System, Ltd) and the mixture was filtered. For titratable acidity, using the same homogenates, 1 ml of the roe filtrate mixed with 99 ml of deionized water then was determined by titrating against 0.1N standard sodium hydroxide (NaOH) solution. Complete titration was achieved when the colour turned to pink against three drops of phenolphthalein indicator. The % (v/v) acid in the sample was calculated as lactic acid using the following formula:

$$Acidity = \frac{0.009\ x\ ml\ of\ 0.1\ N\ NaOH\ x\ F\ x\ 100}{Sample\ (ml)}$$

2.3.4. Salt content

Salt content of the roe product was determined using the titrimetric method according to the AOAC (1995). Preparation of the sample for the chloride ion concentration was done by placing 1 ml of roe filtrate (prepared for acid value determination) into a 250 ml of Erlenmeyer flask, and made up to a final volume of 100 ml with deionized water. Small quantities of $NaHCO_3$ were added in order to adjust the pH of the solution to 7 and a 2 ml of potassium chromate was added to the mixture. The mixed solution then was

titrated with 0.1M of standard silver nitrate solution to the first permanent appearance of red-brown Ag_2CrO_4 achieved.

2.3.5. Water activity

Water activity was measured at 25ºC using a water activity meter (Aqualab Dew Point Model 4TE) on fish roe product before freeze-drying. The analysis was done according to the manufacturer instructions.

3. RESULTS AND DISCUSSION

3.1. Roe skeins of the weight and size

Individual roe skeins had an average weight of 301.31 ± 63.70 g (ranged 200.9 to 422.5 g), length 25.75 ± 3.11cm (ranged from 20.0 to 30.0 cm), and the width 6.21 ± 1.31 cm (ranged between 4.5 and 9.0 cm). In this study, only whole skeins (intact and un-damaged) roes were used, the size of fish roe can be very important consideration that could influence the processing conditions (e.g. salting, drying/fermentation times, salt penetration rate) and suitability of the fish roes for certain products (e.g. product like caviar, salted-, dried- or fermented roe products).

Table 1. Average (mean ± SD) values of weight and size (length and width) of the skeins of fresh salmon roe used in the present research.

Parameter	Mean ± SD	Range
Weight (g)	301.31 ± 63.70	200.9 – 422.5
Length (cm)	25.75 ± 3.11	20.0 – 30.0
Width (cm)	6.21 ± 1.31	4.5 – 9.0

3.2. Colour of the raw roes and salted-dried roe product

Colour and appearance attract the consumers to a product and can support marketing of the product. Colour parameters characterized as lightness (L*), redness (a*), yellowness (b*), chroma (C*), and hue (h*) for raw and processed (salted-dried) roes are shown in Table 2. During 20 days of drying, the roe reduced the colour from red-pink (day 0) to dark red-brown (after day 20 of processing). The a* value decreased from a 24.49 ± 3.27 (at day 0) to a 5.18 ± 0.95 (at day 20), also to the b* value decreased from a 24.88 ± 2.01 (at day 0) to a 3.44 ± 0.96 (at day 20). However, the L* value decreased with the progression of salt drying periods up to day 8 from an average of 45.51 ± 4.31 (at day 0) to 33.00 ± 6.20 (at day 8). Then, followed by the rising up to 39.58 ± 3.19 at the end of salt drying time. The migration of moisture, salt uptake during incubation could affected pigments in the roe, leading to reduction in the redness and chroma. According to (Hayabuchi et al., 1997), processing condition, such as salting, generally controls the colour of the final product due to chemical changes and reduction of moisture. Studies by Bekhit et al. (2009a) on six different New Zealand fish species and Bekhit et al. (2018) on hoki roe found that processing (e.g. fermentation) at different fish species, temperatures and times could affect the microbiological status

and the physicochemical properties of the final product, including colour, as these factors play important part in streamlining quality procedures.

Table 2. Colour changes in salted-dried salmon roe processed at 4ºC.

Fermentation days	L* (Lightness)	a* (Redness)	b* (Yellowness)	C* (Chroma)	HA* (Hue angle)
0	45.51±4.31	24.49±3.27	24.88±2.01	34.99±2.82	45.59±4.36
4	27.45±1.18^{d}	15.45±2.09^{b}	11.25±2.02^{b}	19.14±2.75^{b}	35.95±2.79^{bc}
8	25.95±3.31^{d}	9.75±2.02^{c}	7.69±2.30^{c}	12.46±2.90^{c}	37.84±3.88^{b}
12	33.00±6.20^{c}	12.67±1.92^{bc}	9.49±1.69^{bc}	15.84±2.46^{bc}	36.752±2.51^{bc}
16	38.66±3.05^{b}	5.75±1.54^{d}	3.71±1.35^{d}	6.86±2.00^{d}	32.13±3.73^{c}
20	39.58±3.19^{b}	5.18±0.95^{d}	3.44±0.96^{d}	6.23±1.27^{d}	33.25±4.12^{bc}

Each value is the mean ± standard deviation of measurements in three individual roe skeins (n=3).
$^{a-d}$ Values in the same column with different superscript are significantly different ($P<0.05$).

3.3. Chemical composition

3.3.1. Proximate

Table 3 gives the effect of salt drying during fermentation time over 20 days on the chemical compositions of the raw salmon roes compared to the salted-dried roes. The moisture content was reduced significantly ($P<0.05$) by about 30% due to the salting out and drying effects from 56.41 ± 0.57% (at day 0) to 25.44 ± 2.72% (at day 20). The loss in moisture was accompanied by increases in ash content, which reflect the increase in salt concentration as well as the apparent increase due to drying process. The ash content increased significantly ($P<0.05$) from 2.34 ± 0.29% at zero time to 6.70 ± 1.11% at the end of drying time.

The protein content of the raw roes was 27. 51 ± 0.26 %. At the end of the processing, the protein content of the roe had increased to 40.39 ± 0.21%. The reason for the protein rate being higher is moisture loss, which may be due to increase of dry matter. Rodrigo et al. (1998) when salting and drying the roe from Hake and Ling fish found that the protein content in the final product ranged between 39.1% and 43.6%, respectively. The obtained results are in agreement with the results performed by Rodrigo et al. (1998).

The percentage of lipid content of the salted-dried salmon roes also exhibited an increasing trend during the salted-drying process. The lipid content of the raw roe was 10.30 ± 1.41% and as salt drying time progressed, the final product had a lipid content higher between 12.83 ± 1.83% and 18.05 ± 2.54%. The changes in the lipids content over the processing time is due to the salt-out and salt-in process throughout the roe skein. The apparent increase in lipid content could be due to the decrease in moisture due to the salting effect and the increased osmosis outside the roe skein. The crude lipid contents found in this study was in the range reported by Bledsoe et al. (2003) for salmon roe products which ranged from 8% to 25%. Mol and Turan (2008) also stated that the lipid content found in red salmon roe was 26.8% and

Bekhit et al. (2009b) reported that lipid content of mature and immature chinook salmon roe was 10.6% and 8.4%, respectively.

The carbohydrate content of the salted and dried roes ranged between 3.43 ± 1.03% and 9.42 ± 1.51 %. In general, the carbohydrate content increased during the process (Bekhit et al., 2018). The increase in carbohydrate may due to the decrease in moisture content due to the salt drying method.

The energy value of the raw roe was 211.78 ± 0.57 kcal/100g. Salt drying increased the energy value to 370.92-± 16.67 Kcal/100g at the final day of process, which can be attributed mostly to a loss in moisture content and an apparent increase in other components (Bekhit et al., 2018).

3.3.2. pH and acidity value

The pH and acidity value are factors that are used as indicators of degree of freshness or spoilage and have an impact on product safety and flavour during the development of the fermentation (salted-dried and salted-fermented) process (Bekhit et al., 2018). The changes in pH and acidity value of the roe were observed over the 20 days of salted-drying (Table 3). The initial pH of raw roe was 5.74. This value is in agreement with that of Bledsoe et al. (2003) who reported the pH value of the salmon roe products varied between 5.5 and 5.8. Bekhit et al. (2009b) found that the pH of mature salmon roe was 5.62. In this study, pH value remained constant during processing, but a slight decrease to 5.65 was found at the end of processing time. This finding and previous findings might be attributed to from which the roes were obtained and the different treatments or processing applied. According to statistical assessment performed in this current study, the different was significant ($P<0.05$) during salt drying throughout the entire processing period.

The acid value of the samples which are expressed as percent lactic acid, varied ($P<0.05$) with the increasing of salt drying time. At the first 12 days of salt drying, the acid value was 0.18 ± 0.03% risen from 0.05 ± 0.01% when the roe was unprocessed. There was a slight reduction in value after day 16 (0.16 ± 0.03%) and at the final day of processing where the acid value declined to 0.014 ± 0.02%. The fluctuated acid value according to Adams and Hall (1988) implied that the growth of LAB that produces mixtures of organic acids occurred during the process of salt drying.

3.3.3. Salt content

The salt content of raw roe was 0.58 ± 0.02% and to be 5.29 ± 1.37% by the 20th day in salt drying process. The increase in the salt content is due to partial dehydration and salt migration to the roes. The salt content has a significant linear increasing effect on the moisture content ($P<0.05$), which gradually reduced during process of salt drying. Mean values of the salt content obtained in the salted-dried salmon roe were between 3.03 ± 0.15% (at day 4) and 5.29 ± 1.37% (at the final day of processing). According to Horner

(1997), the salt concentration above 5%, inhibited most of the microorganisms associated with spoilage are halo-phobic.

3.3.4. Water activity

The availability of water (a_w) measured for the raw roe was 0.98 and decreased to 0.82 up to 20 days of salted-drying. According to Hsu and Deng (1980) salting (15% solid salt) of mullet roe resulted in water loss and salt uptake, which depressed the water activity from 0.975 to 0.858. While, water activity increased after desalting due to water absorption and decreased salt content. The decrease in a_w limits favourable condition for the growth of spoilage microorganisms as studied by Labuza and Rahman (2007) which recorded that the water activity below 0.85–0.86 inhibits pathogenic bacteria, while yeast and moulds are more tolerant to a reduced water activity and cannot grow when water activity is 0.62.

Table 3. Physicochemical compositions following cold incubation at 4°C of salted-dried salmon roe for over 20 days.

d	Fermentation time (days)					
	0	4	8	12	16	20
Moisture (%)	56.41 ± 0.57^{a}	43.87 ± 4.14^{b}	38.63 ± 4.01^{bc}	32.18 ± 1.48^{cd}	27.54 ± 1.83^{d}	25.44 ± 2.72^{d}
Lipid (%)	10.30 ± 1.41^{c}	12.83 ± 1.51^{bc}	13.71 ± 1.68^{abc}	17.21 ± 1.33^{ab}	17.23 ± 1.62^{ab}	18.05 ± 2.54^{a}
Protein (%N x 6.25)	30.16 ± 0.29^{d}	34.37 ± 1.61^{c}	36.28 ± 0.84^{c}	40.38 ± 2.77^{b}	45.95 ± 0.86^{a}	44.29 ± 0.23^{ab}
Ash (%)	2.34 ± 0.29^{b}	6.52 ± 0.65^{a}	6.27 ± 1.27^{a}	6.39 ± 1.32^{a}	5.36 ± 1.51^{ab}	6.70 ± 1.11^{a}
Carbohydrate (%)	3.43 ± 1.03^{b}	5.44 ± 2.34^{ab}	8.30 ± 0.91^{ab}	7.40 ± 1.13^{ab}	7.97 ± 3.85^{ab}	9.42 ± 1.51^{a}
Energy value (Kcal/100g)	211.78 ± 0.57^{d}	262.3 ± 24.4^{c}	289.0 ± 19.9^{bc}	331.79 ± 14.94^{ab}	353.11 ± 7.02^{a}	370.92 ± 16.67^{a}
pH	5.74 ± 0.01^{a}	5.73 ± 0.01^{ab}	5.70 ± 0.02^{b}	5.75 ± 0.01^{a}	5.71± 0.03^{b}	5.65 ± 0.03^{c}
Acidity value (%)	0.05 ± 0.01^{e}	0.09 ± 0.01^{d}	0.12 ± 0.02^{c}	0.18 ± 0.03^{a}	0.16 ± 0.03^{b}	0.14 ± 0.02^{bc}
Salt content (%)	0.58 ± 0.02^{d}	3.03 ± 0.15^{c}	3.67 ± 0.30^{bc}	3.99 ± 0.75^{bc}	4.52 ± 0.46^{ab}	5.29 ± 1.37^{a}
Water activity (A_w)	0.98 ± 0.01^{a}	0.90 ± 0.00^{b}	0.86 ± 0.00^{c}	0.84 ± 0.02^{d}	0.83 ± 0.01^{de}	0.82 ± 0.00^{e}
Weight loss (%)	100.0 ± 0.00	85.31 ± 1.42	76.49 ± 1.78	71.64 ± 1.97	68.61 ± 2.19	67.44 ± 2.32

Each value is the mean ± standard deviation of three replicates (n=3).
$^{a-e}$values in the same row with different superscript are significantly different ($P<0.05$).

4. CONCLUSION

Present results indicate that application of salted-drying over 20 days resulted in significant colour change, from red-pink (day 0) to dark red-brown (after day 20 of processing). Salted-drying produced higher protein, lipid, ash, carbohydrate, and energy value compared to the unprocessed roe. Salt drying time and moisture content was found to have a good correlation with pH values, acidity, salt content and aw which can contribute to a more in-depth and understanding of the organisms that involved and their roles in process of salt drying in reducing or increasing bioactive compounds.

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Oral Session | Food Function/Nutrition
[4-1330-C] Functional/Wellness Foods &Nutrition (1)
Wed. Sep 4, 2019 1:30 PM - 2:30 PM Room C (3rd room)

[4-1330-C-03] Effect of Inulin and *Carissa carandas* L. Supplementation on Physicochemical and Microbiological Properties of Frozen Yogurt

*Kamonwan Manowan[1,2], Ni-orn Chomsri[1,2] (1. Agricultural Technology Research Institute, Rajamangala University of Technology Lanna(Thailand), 2. Faculty of Sciences and Agricultural Technology, Rajamangala University of Technology Lanna(Thailand))

Keywords: Frozen yogurt , Inulin , Carissa carandas

Frozen yogurt is a frozen dessert claimed to confer health benefits due to the remaining viable bacteria. This study investigates the influence of using inulin and *Carissa carandas* L. (CC) as supplements in the frozen yogurt mixture on the properties of frozen yogurts. The samples were examined for their color, melting behavior, chemical composition, lactic acid bacteria count and sensory evaluation. The results showed that increasing CC contents in the mixtures resulted in higher color values of a* and chroma in the frozen yogurts. Inulin and CC supplementation at the higher levels in frozen yogurts showed higher total solid contents ($p \leq 0.05$). CC supplementation in frozen yogurts at higher levels significantly improved phytochemical properties of final products. Analysis of melting behavior revealed that the melting rate was retarded when higher levels of inulin and CC were employed in the frozen yogurt production. The frozen yogurt containing inulin at 5% and CC at 15% showed a slight reduction of a viable lactic acid bacteria (LAB) count of 0.68 log CFU/g after 90 day-storage at -18 ^{o}C. Sensory results indicated a positive effect of inulin and CC supplementation on the sensory attributes of frozen yogurts.

Effect of Inulin and *Carissa carandas* L. Supplementation on Physicochemical and Microbiological Properties of Frozen Yogurt

Niorn Chomsri[*1/2], Kamonwan Manowan[1/2]

[1]Agricultural Technology Research Institute, Rajamangala University of Technology Lanna, Thailand
[2]Faculty of Sciences and Agricultural Technology, Rajamangala University of Technology Lanna, Thailand

*Corresponding author: niornchomsri@rmutl.ac.th

ABSTRACT

Frozen yogurt is a frozen dessert claimed to confer health benefits due to the remaining viable bacteria. This study investigates the influence of using inulin and *Carissa carandas* L. (CC) as supplements in the frozen yogurt mixture on the properties of frozen yogurts. The samples were examined for their color, melting behavior, chemical composition, lactic acid bacteria count and sensory evaluation. The results showed that increasing CC contents in the mixtures resulted in higher color values of a* and chroma in the frozen yogurts. Inulin and CC supplementation at the higher levels in frozen yogurts showed higher total solid contents ($p \leq 0.05$). CC supplementation in frozen yogurts at higher levels significantly improved phytochemical properties of final products. Analysis of melting behavior revealed that the melting rate was retarded when higher levels of inulin and CC were employed in the frozen yogurt production. The frozen yogurt containing inulin at 5% and CC at 15% showed a slight reduction of a viable lactic acid bacteria (LAB) count of 0.68 log CFU/g after 90 day-storage at -18 ºC. Sensory results indicated a positive effect of inulin and CC supplementation on the sensory attributes of frozen yogurts.

Keywords: Frozen yogurt Inulin *Carissa carandas*

1. INTRODUCTION

Frozen yogurt, one of frozen dessert is a yogurt ice cream and generally recognized as functional food because LAB starter i.e. *Streptococcus thermophilus* and *Lactobacillus bulgaricus* in yogurt is claimed to confer health benefits (Brunning, 2017; Mena and Aryana, 2018; Das et al., 2019; Terpou et al., 2019; Wasilewska et al., 2019). Furthermore, yogurt has been known as versatile bioactivity including immunity stimulation, gastric disorder treatment, pathogen and intestinal infection protection, diarrhea alleviation, lactose utilization improvement (Feng et al., 2008; Patro-Golab et al., 2015; Aryana and Olson, 2017). However, supplementation of functional ingredients into frozen yogurt may increase beneficial properties on the product regarding consumers' awareness for healthier. Thus, a variety of food ingredients and processing aspects have been examined by researchers to improve the quality of frozen yogurts such as addition of prebiotics and fruits possessing unique and specific functions (Isik et al., 2011; Chanasith et al., 2017; Terpou et al., 2019). Among these practices, supplementation of inulin, a natural polysaccharide belongs to the fructan family has been used widely in frozen yogurt, typically in order to act as prebiotics (Kaur and Gupta, 2002; Yang et al., 2018), enhance probiotic survival (Criscio et al., 2010; Pinto et al., 2012) and improve textural properties of the products (Isik et al., 2011; Muzammil et al., 2017).

CC, botanical name, *Carissa congesta* belonging to Apocynaceae family is an evergreen, spiny shrub and found in Malaya, Thailand, India, Napal, Sri Lanka, Myanmar, Malaysia, Philippines, Cambodia, Vietnam and East Africa (Weerawatanakorn and Pan, 2016; Mohammad et al., 2019). CC has been called Namdaeng (red thorn) or Manao Mai Ru Ho in Thailand (Yuenyongphutthakal et al., 2012; Pewlong et al., 2014; Chomsri et al., 2018). The fruit turns from pinkish white to dark red when ripe and can be eaten raw or processed (Chomsri et al., 2018). The interest in CC has increased during the last decade, because of its pharmacological characteristics, e.g. treatment of constipation, diarrhea, stomachic, anorexia, intermittent fever, mouth ulcer, sore throat, syphilitic pain, burning sensation, scabies and epilepsy (Mehmood et al., 2014, Khatun et al., 2017; Bahdane and Pati, 2017; Singh et al., 2018; Virmani et al., 2017; Madhuri and Neelagund, 2019). The prominent functional properties of the

CC berry fruit, e.g. antioxidant properties, anti-inflammatory effect and biocolorant (Weerawatanakorn and Pan, 2016; Sarkar et al., 2018) shed light on its application in food industry.

The aim of this study was the production of functional frozen yogurt by adding inulin and CC. The influence of added inulin and CC on chemical, physical, and sensorial characteristics of produced frozen yogurt was studied. Moreover, the survival of LAB during frozen yogurt storage was evaluated.

2. MATERIALS AND METHODS

2.1 Frozen yogurt preparation

The experiment was carried out at Agricultural Technology Research Institute, Rajamangala University of Technology Lanna, Lampang, Thailand. Two factors of inulin contents at two levels (0 and 5%) and CC berry contents at 2 levels (10 and 15%) were designated to add in the ice cream mixture for the production of frozen yogurt. Yogurt was produced by adding commercial yogurt culture into pasteurized cow's milk. The mixture of milk and starter yogurt culture was incubated at 45 °C for 5 h. Then, inulin, CC berry, whipping cream, skim milk powder, fructose syrup, and stabilizer were blended with the yogurt at the proportion of 1:1 for ice cream mix preparation. The ice cream mixes were aged at 4 ºC for 12 hours. Subsequently, four different frozen yogurt treatments: Frozen yogurt 1; inulin content 0% and CC berry content 10% (I0CC10), Frozen yogurt 2; inulin content 0% and CC berry content 15% (I0CC15), Frozen yogurt 3; inulin content 5% and CC berry content 10% (I5CC10) and Frozen yogurt 4; inulin content 5% and CC berry content 15% (I5CC15) were submitted to the ice cream maker (Model Gel M4, Staff Ice System, Italy). Frozen yogurt samples were packed in cups of 30 ml hardened and stored at −18 °C.

2.2 Physicochemical Analysis of frozen yogurt

The total solids in the frozen yogurt mixture were determined by modified method of Nielsen (2017). pH was measured by digital pH meter (Model C831, Belgium). Total acidity was determined by diluting each 5 ml aliquot of sample in 50 ml distilled water and then titrating to pH 8.2 using 0.1 N NaOH (Iland et al., 2000). Titratable acidity was expressed as lactic acid percentage. Total soluble solid content was determined on an Atago hand-held refractometer. Free alpha amino nitrogen (FAN) was quantified by spectrophotometric method (Intaramoree and Chomsri, 2014). Total anthocyanin content was evaluated by the method of Giusti and Wrolstad (2005). The modified method of Spínola et al. (2015) was used to evaluate total phenolic content. The antioxidant activity was determined by modified method of Wongputtisin et al. (2007).

2.3 Melting behavior of frozen yogurts

The melting behavior was measured according to the method proposed by Arbuckle (1986). The melting rate was calculated by taking 25 g frozen yogurt sample and placing it on a wire mesh screen over a graduated cylinder at 25°C. The dripped mass was recorded every 10 minutes for 60 minutes. The melting rate was calculated by dividing the melted sample over time (g/min). The mass of melted ice cream (%w/w) was plotted against time (min). Melting behavior was determined after one week of frozen storage. This analysis was performed in triplicate.

2.4 Microbiological enumeration

For the enumeration of viable cell counts, 10 g samples were collected from each frozen yogurt directly after packing and the sample I5CC15 at various time intervals (0, 60 and 90 days after manufacturing) during storage at −18 °C. The samples were serially diluted in 90 mL sterile Ringer's solution, diluted and plated on MRS medium.

2.5 Sensory analysis

All the panelists were experienced in frozen yogurt or ice cream. A group of 30 panelists took part in this study. Frozen yogurt products fermented for 2 weeks were evaluated for organoleptic quality. The samples of frozen yogurt were served in random order at −18°C in plastic cups identified with a random 3-digit code. The panelists were suggested to rinse their mouths with water between samples. The panelists were asked to rate the products on the 9-point hedonic scale (Meilgaard et al., 2006)

2.6 Statistical analysis

All the experiments were carried out with replications. Analysis of variance (ANOVA) was used to compare mean differences of the samples. Significant differences between treatments were analyzed by Duncan’s new multiple range test (DNMRT) at a 0.95 significance level. Values were expressed as the mean of all replicate determinations with standard deviation.

3. RESULTS AND DISCUSSION

3.1 Physicochemical characteristics

Color analysis of the CC frozen ice creams (Figure 1) was performed and recorded as shown in Table 1. There were significant effects of CC and inulin supplementation on a* (redness) chroma and hue values as interaction. Frozen yogurts from CC contents of 15% showed an increase in a* chroma values compared to frozen yogurts from CC contents of 10%. These results suggest that frozen yogurts from CC contents of 15% showed intensively reddish colors compared with frozen yogurts from CC contents of 10%. This result is associated with an amount of red pigments containing in CC (Mohammad and Ding, 2019).

a b c d

Figure 1. CC frozen ice creams from different supplementation of inulin and CC contents; a) inulin content 0% and CC berry content 10%, b) inulin content 0% and CC berry content 15%, c) inulin content 5% and CC berry content 10% and d) inulin content 5% and CC berry content 15%

Table 1. Color values of CC frozen ice cream from different supplementation of inulin and CC contents

Treatments	L*	a*	b*	chroma	hue
	ns	*	ns	*	*
I0CC10	55.24±0.34	12.79±0.00^{b}	1.27±0.01	12.86±0.00^{ab}	5.70±0.04^{a}
I0CC15	54.70±1.52	14.91±0.00^{ab}	0.73±0.17	14.93±0.01^{a}	2.80±0.66^{b}
I5CC10	54.71±5.44	10.47±1.47^{c}	1.98±2.08	10.73±1.82^{b}	3.05±0.02^{b}
I5CC15	53.70±2.45	15.27±0.61^{a}	0.28±0.16	15.27±0.61^{a}	1.08±0.65^{c}

ns denotes means are not significantly different ($p>0.05$)

* Means in a column with the different letters represent significant differences ($p\leq0.05$)

Inulin content 0% and CC berry content 10%; I0CC10, inulin content 0% and CC berry content 15%; I0CC15, inulin content 5% and CC berry content 10%; I5CC10, and inulin content 5% and CC berry content 15%; I5CC15

The effect of inulin and CC supplementation on total solid contents is displayed in Table 2. Inulin and CC supplementation at the higher levels in frozen yogurts led to higher total solid contents ($p\leq0.05$). A significant increase of the total solid contents in the frozen yogurt samples by the supplementation of inulin correlated to that of Muzammil et al. (2017), where the frozen ice cream containing 6% inulin had the total solid content higher than the frozen ice cream containing 2% inulin. Total solid contents of CC frozen ice creams ranged from 25 and 33%, while Muzammil et al. (2017) and Isik et al. (2011) reported the total solid contents of frozen yogurts in the ranges of 32% and 35%. The CC supplementation affected the total solid content may be explained by the solid parts found in CC berries such as organic acids, sugars, pigments and fibers (Sarkar et al., 2018; Mohammad and Ding, 2019).

The pH and acidity of various treatments did not differ obviously. However, the results demonstrated that frozen yogurts containing 15 % CC had significantly lower pH and higher total soluble solid contents than frozen yogurts containing 10% CC ($p<0.05$) as shown in Table 2. The natural titratable acidity of the samples depended on the components containing in the CC frozen ice creams, e.g. lactic

acid in the yogurt and organic acids in the CC. The lowest pH and highest total soluble solid content values were observed in the sample containing inulin 5% and CC 15%. This was probably due to the high acid content in the CC fruits as noted by Chomsri et al. (2017).

Table 2. Chemical property of CC frozen yogurts

Factor	TS (%)	pH	TA (%)	TSS (°Brix)
Inulin content (A)	*	ns	ns	*
0% (I0)	26.03±1.29^{b}	3.92±0.06	1.02±0.05	22.25±2.36^{b}
5% (I5)	31.61±2.47^{a}	3.89±0.09	0.09±0.07	25.66±3.01^{a}
CC content (B)	*	*	ns	*
10% (CC10)	27.26±2.30^{b}	3.98±0.01^{a}	0.95±0.03	21.58±1.74^{b}
15% (CC15)	30.38±3.91^{a}	3.83±0.03^{b}	1.05±0.03	26.33±2.25^{a}
A*B	*	*	ns	ns
I0 x CC10	25.16±0.20^{d}	3.97±0.02^{a}	0.97±0.00	20.16±0.76
I0 x CC15	29.36±0.17^{b}	3.86±0.06^{b}	1.07±0.01	24.33±0.57
I5 x CC10	26.90±1.37^{c}	3.98±0.01^{a}	0.93±0.04	23.00±1.00
I5 x CC15	33.86±0.18^{a}	3.81±0.01^{c}	1.04±0.04	28.33±0.57

ns denotes means are not significantly different ($p>0.05$)
* Means in a column with the different letters represent significant differences ($p\leq0.05$)
Total solid content; TS, total acidity (%); TA, total soluble solids (°Brix); TSS, inulin content 0%; I0, inulin content 5%; I5, CC berry content 10%; CC10 and CC berry content 15%; CC15

The concentrations of total anthocyanin, phenolic, and antioxidant activity in frozen yogurts from different supplementation of inulin and CC contents varied from 10.26 to 13.75, 370 to 460 mg/kg and 55.61 to 71.89 % scavenging effect, respectively. The significant effects of CC supplementation on phytochemical values were observed. Frozen yogurts from CC contents of 15% had higher antioxidant activity ($p\leq0.05$) compared to frozen yogurts from CC contents of 10%. The highest antioxidant activity with 32.17 mg ascorbic acid equivalent/100g sample and 49.88 mg Trolox equivalent /100g sample was achieved in the frozen yogurt containing 5% inulin and 15% CC. This could be explained by CC contains high levels of anthocyanins and phenolic compounds (Pewlong et al., 2014; Weerawatanakorn and Pan, 2016; Chomsri et al., 2017; Sarkar et al., 2018). These substances are most typically responsible for the antioxidant activity exhibited in CC frozen yogurts.

Table 3. Phytochemical contents and antioxidant activity of CC frozen yogurts

Factor	TAC (mg/kg)	TPC (mg/kg)	AO (%)	AOA (mg/100g)	AOT (mg/100g)
Inulin content (A)	ns	ns	ns	ns	ns
0% (I0)	12.00±1.98	434±69	62.49±5.35	27.94±2.39	43.36±3.71
5% (I5)	13.09±3.49	418±78	63.75±9.00	32.17±0.62	44.24±6.24
CC content (B)	*	*	*	*	*
10% (CC10)	10.46±0.98^{b}	382±55^{b}	56.66±1.81^{b}	25.34±0.80^{b}	39.32±1.25^{b}
15% (CC15)	14.64±2.34^{a}	471±56^{a}	69.58±2.69^{a}	31.13±1.21^{a}	48.28±1.87^{a}
A*B	ns	ns	*	*	*
I0 x CC10	10.26±0.17	394±83	57.71±1.75^{c}	25.81±0.78^{c}	40.05±1.21^{c}
I0 x CC15	13.75±0.82	475±7	67.27±0.30^{b}	30.08±0.13^{b}	46.68±0.21^{b}
I5 x CC10	10.67±1.50	370±19	55.61±1.36^{c}	24.87±0.61^{c}	38.59±094^{c}
I5 x CC15	13.09±3.49	460±88	71.89±1.45^{a}	32.17±0.62^{a}	49.88±1.00^{a}

ns denotes means are not significantly different ($p>0.05$)
* Means in a column with the different letters represent significant differences ($p\leq0.05$)
Total anthocyanin content (mg/kg); TAC, total phenolic content (mg GAE/kg); TPC, antioxidant activity (% scavenging effect); AOA, inulin content 0%; I0, inulin content 5%; I5, CC berry content 10%; CC10 and CC berry content 15%; CC15

3.2 Melting behavior of frozen yogurts

Melting is an important assessment criteria of ice cream quality. Many factors influences melting of ice cream, e.g. total solid content, size of the ice particles, amount and size of the fat particles, composition in the mixture, stabilization, presence of air in ice cream (Clarke, 2004; Alfaro et al., 2014; Moriano and Alamprese, 2017, Goral et al., 2018). The melting behavior of the frozen yogurts is presented in Figure 2. The dripping of the first drop of melted frozen yogurts containing inulin required 8-10 minutes, whereas melting time of the first drop of frozen yogurts without inulin supplementation was appeared at less than 5 minutes. In addition, higher levels of inulin in CC frozen yogurts reduced melting rates as obviously seen in meltdown curves. The highest melting rate was recorded for the sample with inulin 5% and CC 15%, whereas the lowest melting rate was obtained from the sample with inulin 0% and CC 10%. Similar results were also reported by Akbari et al. (2016) Junyusen et al. (2017), Rezaei et al., (2014) and Isik et al. (2011). Goral et al. (2018) reported melting time of the first drop ranged between 16-25 minutes in coconut milk-based ice cream with different stabilizer addition, whereas Isik et al. (2011) observed the first drop that frozen yogurts added inulin and isomalt between 8.5-13.5 minutes. This means that components in frozen yogurts substantially affects the melting behavior of the products.

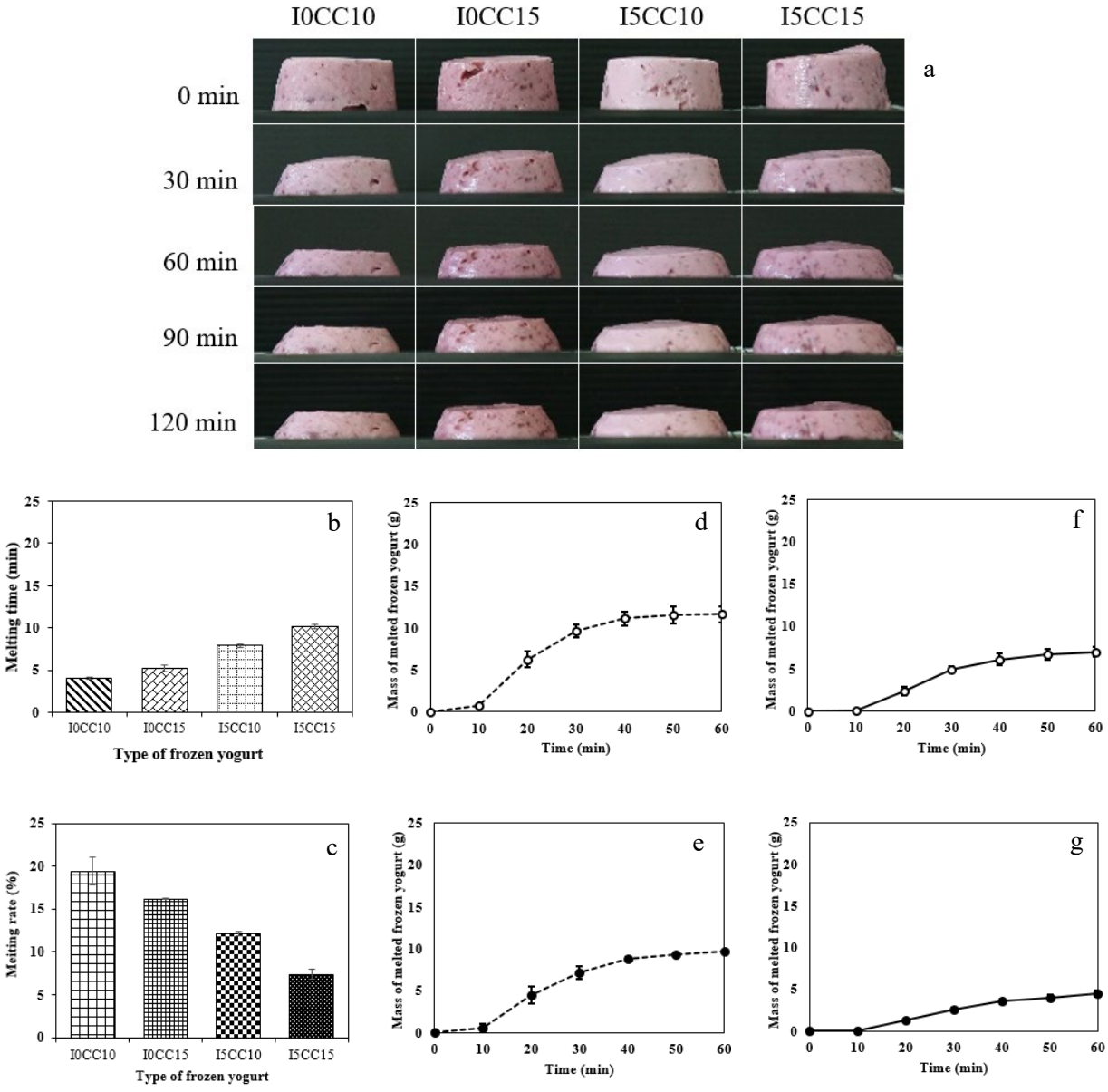

Figure 2. Melting profiles of frozen yogurts from different supplementation of inulin and CC contents; a) pictures taken during melting tests, b) the dripping of the first drop, c) melting rate and d) melted mass of frozen yogurts d) inulin content 0% and CC berry content 10%; I0CC10, e) inulin content 0% and CC berry content 15%; I0CC15, f) inulin content 5% and CC berry content 10%; I5CC10 and g) inulin content 5% and CC berry content 15%; I5CC15

3.3 Microbiological enumeration

Surviability of cultures is an important quality for frozen yogurt. Initial counts of lactic acid bacteria in the frozen yogurts from different supplementation of inulin and CC ranged between 6.29-6.72 log CFU/g. According to the sensorial evaluation, the sample with inulin 5% and CC 15% was monitored in order to study survivability of lactic acid bacteria in the frozen yogurt. Microbiological results revealed that LAB survival remained in the range of 6.58 to 5.90 log CFU/ g during 90 day-storage at -18 ^{o}C. LAB counts declined 0.68 log CFU/g compared to the initial counts. In the present study, only a slight reduction of LAB count was observed, although stress factors, e.g. sublethal injuries caused by freezing, the presence of oxygen in the product could affect the cell viability (Leando et al., 2013; Rezaei et al., 2014). LAB survival in this study could possibly indicate resistant to severe conditions of starter cultures and inulin supplementation could improve their survivability during freezing. These results are in agreement with previous reports by Muzammil et al. (2017), Hong and Marshall (2001) and Rezaei et al. (2014). The finding in this study confirmed that LAB in the frozen yogurt could remain viable in the CC frozen yogurt product and during frozen storage.

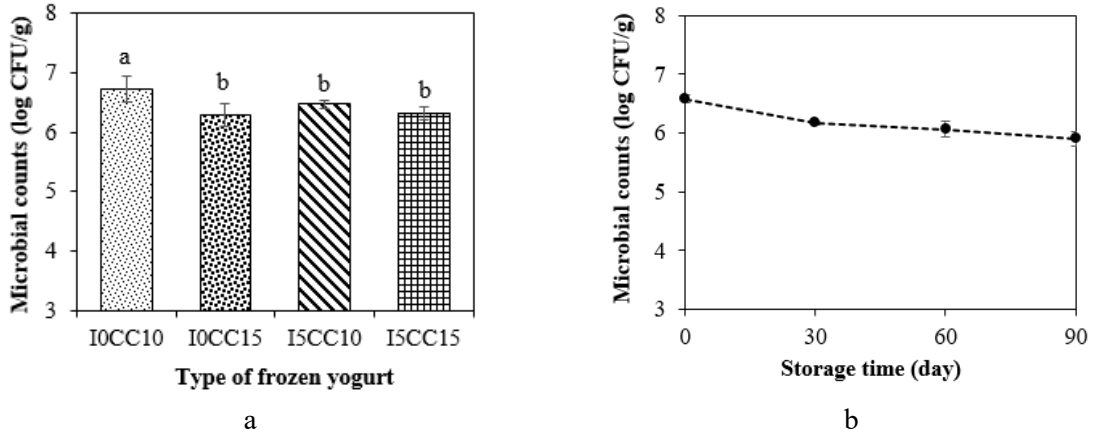

Figure 3. Initial viable counts of lactic acid bacteria in CC frozen yogurts from four treatments (a) and changes of viable counts in the frozen yogurt containing 5% inulin and 15% CC during storage at -18 ^{o}C (b), inulin content 0% and CC berry content 10%; I0CC10, inulin content 0% and CC berry content 15%; I0CC15, inulin content 5% and CC berry content 10%; I5CC10, and inulin content 5% and CC berry content 15%; I5CC15

3.4 Sensory analysis

Sensorial properties revealed the significant effect of supplementation of inulin and CC on the attributes of flavor, texture and overall preference in frozen yogurts ($p \leq 0.05$). Hedonic scores of a texture attribute was significantly higher in the frozen yogurts containing higher levels of inulin contents compared with the frozen yogurts containing lower levels of inulin contents (Figure 4). Inulin supplementation in the frozen yogurts considerably improved the texture attribute of CC frozen yogurts. These results are in agreement with melting properties of the frozen yogurts as previously discussed. There is no significant difference in overall preference scores between the frozen yogurts with and without inulin supplementation, whereas CC supplementation was the factor statistically influencing the overall preference scores of the frozen yogurts. Frozen yogurts containing 15% CC attained higher hedonic scores in the sensorial attribute of overall preference compared with frozen yogurts containing 10% CC ($p \leq 0.05$).

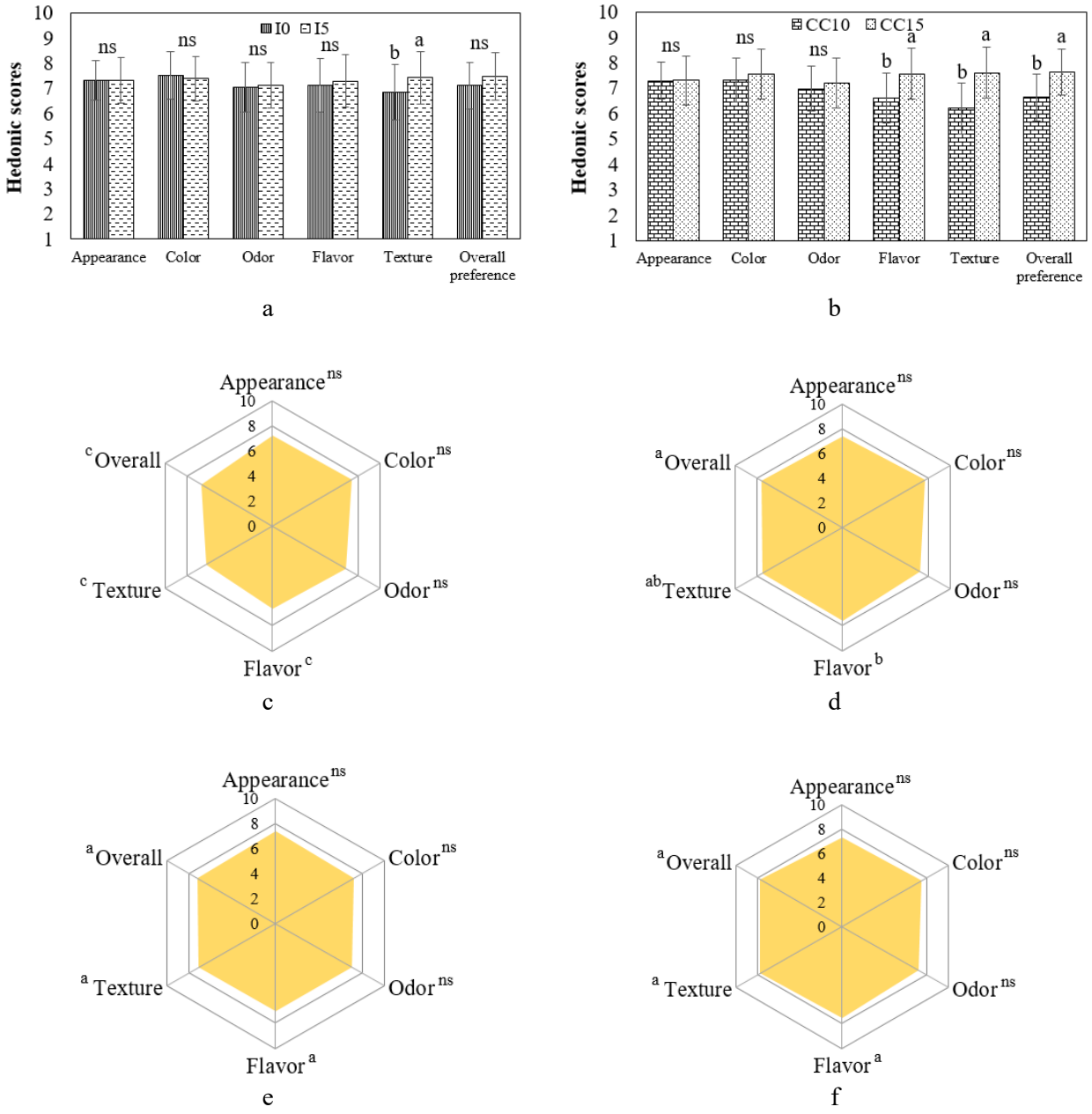

Figure 4. Effect of inulin a) and CC b) supplementation on sensory quality of frozen yogurts, c) inulin content 0% and CC berry content 10%, d) inulin content 0% and CC berry content 15%, e) inulin content 5% and CC berry content 10% and f) inulin content 5% and CC berry content 15%
ns denotes means are not significantly different ($p>0.05$) and means with different letters denote significantly different ($p\leq0.05$).

4. CONCLUSION

This study suggests that inulin supplementation could prolong survival of lactic acid bacteria in CC frozen yogurt. Furthermore, inulin addition into the frozen yogurt mixture could elevate the melting times of the CC frozen yogurt. The conditions to achieve the appropriate production of frozen yogurt were supplementation of inulin and CC into the yogurt at the levels of 5 and 15%, respectively. Inulin and CC fruits have a potential to serve as frozen yogurt ingredients for a healthy diet delivering

multifunctional bioactive components, e.g. peptides, phytochemicals, prebiotics and live microorganisms.

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2:15 PM - 2:30 PM (Wed. Sep 4, 2019 1:30 PM - 2:30 PM Room C)

[4-1330-C-04] Utilization of Banana Agricultural Waste: Effects of Processing Conditions on Properties of Unripe Banana (*Musa Cavendish*) Pulp and Peel Flours

*Natthawuddhi Donlao[1,2], Asia Perin[1], Nasuha Bunyameen[1] （1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai, Thailand(Thailand), 2. Innovative Food Packaging and Biomaterials Unit (IFP), Mae Fah Luang University, Thailand(Thailand)）

Keywords: Antioxidant capacity, Banana peel flour, Banana pulp flour, Citric acid, Drying temperature, Resistant starch

Banana is one of the most important tropical fruits. Flour from green bananas contains a high amount of resistant starch that can reduce constipation, prevent colon cancer and provide benefit to the digestive system. Banana peel is an underused by-product which is known as a potential source of high dietary fiber, protein, essential amino acids, and total phenolic compounds. The objective of this study was to investigate the effects of citric acid pretreatments and drying temperatures on physical, chemical, and functional properties of unripe banana pulp and peel flours. Rejected green bananas (*Musa cavendish*) at the 2nd stage of maturity were obtained from Phaya Meng Rai Agricultural Limited Partnership in Phaya Meng Rai District, Chiang Rai, Thailand. Unripe bananas were washed with clean water and drained. Banana pulps and peels were then separated. The banana pulps and peels were pretreated with citric acid solution at different concentrations (i.e., 0.5, 0.7, and 1.0% w/v) and dried at different temperatures (i.e., 40, 60, and 80 ˚ C). Moisture content, color, water holding capacity, and pasting properties of two flours were determined. Resistant starch of banana pulp flour and total polyphenol content and antioxidant activity of banana peel flour were also determined. In banana pulp flour, higher citric acid concentration and drying temperature resulted in a lower level of moisture content and water holding capacity. The resistant starch increased with increasing drying temperature. Highest peak viscosity was found at the condition of 0.7% citric acid pretreatment. In banana peel flours, total polyphenol content increased with increasing drying temperature. A higher concentration of the citric acid solution and lower drying temperature resulted in increasing *L** value. The highest value of antioxidant capacity was found in the sample dried at 60 ˚ C. It is recommended that pretreating with 1.0% citric acid solution and drying at 80 ˚ C can produce good quality of banana pulp flour. However, good quality of banana peel flour can be achieved by pretreating with 1.0% citric acid solution, followed by drying at 60 ˚ C.

Oral Session | Food Quality

[4-1330-D] Food Quality (2)

Chair:Nurheni Sri Palupi(Bogor Agricultural University, Indonesia)

Wed. Sep 4, 2019 1:30 PM - 2:30 PM Room D (4th room)

[4-1330-D-01] Reducing Allergenicity of Soy Protein Isolate from Local Varieties of Soybean through Glycation with Lactose

*Nurheni Sri PALUPI[1,2], Endang Prangdimurti[1,2], Didah Nur Faridah[1,2], Muhammad Hasriandy Asyhari[3] （1. Department of Food Science and Technology, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University(Indonesia), 2. Southeast Asian Food and Agricultural Science and Technology (SEAFAST) Center, Bogor Agricultural University(Indonesia), 3. Food Science Graduate Program, Graduate School, Bogor Agricultural University(Indonesia)）

1:30 PM - 1:45 PM

[4-1330-D-02] Nutritional Quality of Fertilized and Salted Philippine Mallard Duck (*Anas platyrhynchos L.*) Eggs Consumed in Victoria, Laguna, Philippines

*Lotis Escobin Mopera[1], Pauline Saludo[1], Floirendo Flores[1], Ma. Josie Sumague[1], Bryan Rey Oliveros[1], Wilson Tan[1] （1. Institute of Food Science and Technology, University of the Philippines Los Banos(Philippines)）

1:45 PM - 2:00 PM

[4-1330-D-03] Efficacy of 1-methylcyclopropene (1-MCP) Post-cutting Treatment on the Storage Quality of Fresh-cut ‘Queen’ Pineapple (Ananas comosus(L.) Merr. cv. ‘Queen’)

*Meryl Ancheta Bernardino[1], Katherine Anne Castillo Israel[1], Edralina Serrano[1], James Bryan Gandia[1], Wella Absulio[1] （1. University of the Philippines Los Banos(Philippines)）

2:00 PM - 2:15 PM

[4-1330-D-04] Effect of Direct and Indirect Heating On Heat Stability of Goat Milk

*Souvia Rahimah[1] （1. Universitas Padjadjaran(Indonesia)）

2:15 PM - 2:30 PM

Oral Session | Food Quality

[4-1330-D] Food Quality (2)

Wed. Sep 4, 2019 1:30 PM - 2:30 PM Room D (4th room)

[4-1330-D-01] Reducing Allergenicity of Soy Protein Isolate from Local Varieties of Soybean through Glycation with Lactose

*Nurheni Sri PALUPI[1,2], Endang Prangdimurti[1,2], Didah Nur Faridah[1,2], Muhammad Hasriandy Asyhari[3] (1. Department of Food Science and Technology, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University(Indonesia), 2. Southeast Asian Food and Agricultural Science and Technology (SEAFAST) Center, Bogor Agricultural University(Indonesia), 3. Food Science Graduate Program, Graduate School, Bogor Agricultural University(Indonesia))

Keywords: Allergenicity, Enzyme-Linked Immunosorbent Assay (ELISA), Glycation degree, Soy protein isolate (SPI), SPI-lactose conjugate

Food allergy is a specific immunological response caused by allergens contained in food. Soybean is one of the eight type of food products that often cause allergies that can reduce its quality in term of safety aspect. The soybean processing can reduce the risk of allergies by modifying the structure of the soy protein so as to produce hypoallergenic food. Processing involving the Maillard reaction by conjugating proteins with reducing sugars has the potential to reduce allergenicity. This research aims to: (1) determine the degree of glycation based on the formation of soy protein isolates (SPI)-lactose conjugate and free amino acid; (2) determine the molecular weight profile of SPI and SPI-lactose conjugate: and (3) analyze the allergenicity of SPI-lactose conjugate compared to SPI. Protein isolation was carried out by precipitation of soybean protein of Anjasmoro and Grobogan varieties at their isoelectric point by pH arrangement. Then the SPI was reacted with lactose under pH 9.5 and 95˚C for 60 minutes. Determination of glycation degree of SPI-lactose conjugate was carried out using two methods, namely thiobarbituric acid reactive substances (TBARS) method and Bradford method for free amino acid. The protein molecular weight profile was analyzed using the SDS-PAGE electrophoresis method. Alergenicity of SPI and SPI-lactose conjugate were analyzed quantitatively using the Enzyme-Linked Immunosorbent Assay (ELISA) method. The results showed that the higher protein content in SPI cause higher glycation degree of the SPI-lactose conjugate. SDS-PAGE electrophoresis results showed that the molecular weight profiles of Anjasmoro and Grobogan SPI were 11.3-144.2 kDa and 10.7-159.0 kDa. The glycation process can eliminate or reduce the intensity of protein bands that are suspected to be the major allergen proteins in soybeans, namely Gly m Bd 60K, Gly m Bd 30K or P34, and Gly m Bd 28K. The glycation reaction can reduce allergenicity in local varieties soybeans (Anjasmoro and Grobogan) by 43.12% and 29.85%.

Reducing Allergenicity of Soy Protein Isolate from Local Varieties of Soybean through Glycation with Lactose

Nurheni Sri Palupi[1,2)]*, Endang Prangdimurti[1,2)], Didah Nur Faridah[1,2)], dan Muhammad Hasriandy Asyhari[3)]

[1)]Department of Food Science and Technology, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University
[2)]Southeast Asian Food and Agricultural Science and Technology (SEAFAST) Center, Bogor Agricultural University
[3)]Food Science Graduate Program, Graduate School, Bogor Agricultural University

*Corresponding Author: email: hnpalupi@yahoo.com

ABSTRACT

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Oral Session | Food Quality
[4-1330-D] Food Quality (2)
Wed. Sep 4, 2019 1:30 PM - 2:30 PM Room D (4th room)

[4-1330-D-02] Nutritional Quality of Fertilized and Salted Philippine Mallard Duck (*Anas platyrhynchos L.*) Eggs Consumed in Victoria, Laguna, Philippines

*Lotis Escobin Mopera[1], Pauline Saludo[1], Floirendo Flores[1], Ma. Josie Sumague[1], Bryan Rey Oliveros[1], Wilson Tan[1] (1. Institute of Food Science and Technology, University of the Philippines Los Banos(Philippines))
Keywords: Philippine Mallard Duck, Fertilized Duck Eggs, Salted Duck Eggs, Nutritional Quality

Duck industry is considered as the second largest in the Philippine poultry industry that contributes to farmer’s income through egg and meat production. Ducks are mainly raised for the production of boiled fertilized eggs known locally as *balut* and salted duck eggs.The recent increase in the demand and consumption of these commodities because of diet diversification and utilization, fostered the growth in the duck industry as well as assure sustainable supply of the raw materials for utilization in processing *balut* and salted eggs. To help establish standards for both the quality and safety of *balut* and salted egg, the nutritional property of these two commodities was evaluated in one of the popular towns known to produce *balut* and salted duck eggs. Proximate, mineral and fatty acid analyses of*balut* and salted eggs were done. Both *balut* and salted duck eggs were found to contain considerable amount of protein and calories at 11% and 100%, respectively. In general, the major fatty acids found in duck eggs are oleic acid (C18:1), myristic acid (C14:0) and linolenic acid (C18:2). Salted eggs contained more oleic acid (52.18%) while *balut* has more myristic acid (26.30%). Salted eggs showed higher sodium content as affected by the clay-salt curing process. However, the level of salt still conforms within the recommended nutrient intake for sodium. This study contributes in addressing research gaps in the lack of information for standards and marketing distribution of these products as well as provide information on the nutritional comparison with similar commodities.

Nutritional Quality of Fertilized and Salted Philippine Mallard Duck (*Anas platyrhynchos L.*) Eggs Consumed in Victoria, Laguna, Philippines

Lotis Mopera[1*], Pauline Saludo[1], Floirendo Flores[1], Ma. Josie Sumague[1], Bryan Rey Oliveros[1], Wilson Tan[1]

[1]Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baños, Philippines

*Corresponding author: lemopera@up.edu.ph

ABSTRACT

Duck industry is considered as the second largest in the Philippine poultry industry that contributes to farmer's income through egg and meat production. Ducks are mainly raised for the production of boiled fertilized eggs known locally as *balut* and salted duck eggs. The recent increase in the demand and consumption of these commodities because of diet diversification and utilization, fostered the growth in the duck industry as well as assure sustainable supply of the raw materials for utilization in processing *balut* and salted eggs. To help establish standards for both the quality and safety of *balut* and salted egg, the nutritional property of these two commodities was evaluated in one of the popular towns known to produce *balut* and salted duck eggs. Proximate, mineral and fatty acid analyses of *balut* and salted eggs were done. Both *balut* and salted duck eggs were found to contain considerable amount of protein and calories at 11% and 100%, respectively. In general, the major fatty acids found in duck eggs are oleic acid (C18:1), myristic acid (C14:0) and linolenic acid (C18:2). Salted eggs contained more oleic acid (52.18%) while *balut* has more myristic acid (26.30%). Salted eggs showed higher sodium content as affected by the clay-salt curing process. However, the level of salt still conforms within the recommended nutrient intake for sodium. This study contributes in addressing research gaps in the lack of information for standards and marketing distribution of these products as well as provide information on the nutritional comparison with similar commodities.

Keywords: Philippine Mallard Ducks, Fertilized Duck Eggs, Salted Eggs, Nutritional Quality

1. INTRODUCTION

Processing and consumption of duck eggs has long been done in Asian countries particularly in China, South Korea, Bangladesh, Thailand, Vietnam, Lao, Malaysia, Singapore and Philippines (Tang et al., 2019; Ahmad et al., 2017; Ganesan et al., 2014; Chang and Dagaas, 2004). Apart from its importance as an integral part of the food culture in these countries, duck eggs were also reported as a good source of protein and other nutrients and is regarded as a food with high nutritional quality (Ahmad et al., 2017; Al-Obaidi and Al-Shadeedi, 2016). People eat duck eggs for its high nutritional value because of the optimal composition of essential amino acids and the considerable composition of fatty acids with a high percentage of polyunsaturated fatty acids and a favorable ratio of omega 6- to omega 3-fatty acids. In addition, it is economical as well as quick and easy to prepare and serve.

In the Philippines, the duck industry contributes to 20.32% of the 55.4 billion peso contribution of the poultry industry in the country's Gross Domestic Product (GDP) (PSA, 2019). The duck egg volume of production reached a total of 46.61 thousand metric tons in 2019 (PSA, 2019). This volume grew by 2.60 percent relative to its previous year's level of 45.43 thousand metric tons (PSA, 2019). In general, about 87% of the total duck egg production is processed into *balut* (fertilized duck egg embryo), 7% to salted eggs and the remaining 6% for other duck egg products like century eggs and *penoy* (Chang & Dagaas, 2004).

In terms of production and processing of duck eggs, the town of Victoria in the province of Laguna was dubbed as the "Duck Raising Center of the Philippines" (Atienza et al., 2015). According to the Department of Agriculture (2003), the duck industry in Victoria is a 5.5 billion peso industry which contributes a total duck egg production of 2.5 billion pesos. The town is known for its duck products which include meat and eggs, particularly *balut* and salted egg.

Balut is produced by incubating fertilized duck egg at 40-42.5°C with high humidity. After 18 days, a partially developed embryo can be seen during candling. These "embryonated eggs" are harvested, boiled and sold as *balut*. *Balut* is known to be good but inexpensive source of protein and calcium (Magat, 2002)

along with other nutrients as stated in the Philippine Composition Table (FNRI, 1997). In practice, the infertile eggs can either be processed to salted egg, century egg or *penoy*.

Salted egg is produced by brining or by curing in clay. In most duck farms in the Philippines, curing in clay is often used. This method involves coating duck eggs with a mixture of clay and salt then stored indoors at room temperature for 18 days. After curing, salted eggs are boiled for 20-30 mins prior to consumption. Some producers cover the egg shell with red food colorings or markings for salted eggs to differentiate them from fresh eggs and other egg products as part of the marketing strategy for this egg product.

Both *balut* and salted duck eggs are consumed based on the fact that eggs, in general, are good sources of protein and fat. It also contains dietary macro-minerals (Ca, P, Na, K, Mg) and trace minerals (Fe, Zn, Cu, Mn) (FNRI, 1997). Duck eggs, as in the case of *balut* and salted eggs, are preferred over hen eggs because of its larger size (about 30% bigger) and higher nutritional value which is attributed to higher fat content found in duck eggs (Ahmad et al., 2017). This is because duck eggs contain relatively less water and higher percentage of proteins and fats in the yolk, albumen and total contents of egg as compared to chicken eggs (Rahman et al., 2010).

Variability in the nutritional composition of eggs are dependent on several factors. More often, it is affected by the kind of nutrients fed to the animal. In the Philippines, the feeds for the ducks are normally supplemented with other agricultural products found within the vicinity or location of the duck farms. Another factor that affects the quality of nutrients in duck eggs is the manner of processing. Processing can alter the nutritional composition of the eggs (Ganesan et al., 2014). Thus, it is important to maintain the nutritional quality of the duck eggs even after processing. The maintenance of the egg quality from the time of their production till their delivery to the final consumer is of great importance (Rahman et al., 2010). Information on nutritional composition of duck specifically from the town of Victoria can be a valuable information especially on the marketing strategy of the community involved in processing of the duck eggs from the duck farms in this area. Apart from its economic value, it is necessary to know the nutritional quality of duck eggs for consumer's satisfaction. In addition, the data that was generated from this study on

the nutritional quality can be a benchmark for other localities engaged in duck production and processing, particularly, *balut* and salted duck eggs in the Philippines as well as other countries in Asia engaged in duck production and processing. Thus, a comparative study on the total nutritional quality and value of fresh, fertilized and salted duck eggs from Victoria, Laguna, Philippines were explored.

2. MATERIALS AND METHODS

2.1 Egg Samples

Convenience sampling was employed in the selection of egg samples from outlet stores in Victoria, Laguna from May to July 2018. *Balut* eggs were immediately boiled for 45 mins. All eggs samples were carefully cracked, shells removed and homogenized in the Osterizer blender prior to analysis. Additional sample preparation were done in accordance with succeeding analyses.

2.2 Determination of Proximate and Nutrient Composition of Duck Eggs

Proximate Analysis. Proximate analysis such as moisture, protein, fat, ash and carbohydrate were determined according to AOAC method (2000). Moisture content was determined by oven drying at 105 $\pm$ 5^0C. Protein content (x 6.25) was determined by Kjeldahl method as stated in AOAC (2000). The fat content was determined by Soxhlet method. Ash was determined by incineration of the dried sample at 600^0C for 5 h (AOAC, 2000). The carbohydrate content was computed as nitrogen free extract (NFE) by subtracting the moisture, protein, fat and ash content**.**

2.3 Mineral Analysis. Egg samples were hydrolyzed by wet ashing (AOAC, 2000) using strong acids: nitric acid (HNO_3), perchloric acid ($HClO_4$) and hydrochloric acid (HCl) prior to mineral analysis. Atomic absorption spectrophotometry was used to quantify the minerals in all samples. All mineral concentrations were reported in parts per million (ppm).

2.4 Fatty Acid Profile of Oils extracted from Duck Eggs. Petroleum ether was used to extract oils from egg samples by shaking for 1 h. The extracted oils were placed in vials for storage in the freezer until analysis. Oil samples were submitted to the Central Analytical Services Laboratory, National Institute

for Molecular Biology and Biotechnology, (BIOTECH-UPLB) for fatty acid profiling against fatty acid methyl ester standards using Gas Chromatograph (AOAC 969.33; 963.22, 2000).

2.5 Statistical Analysis

All of the experiments were performed in triplicates, and the results are expressed as means ± SD. Statistical analyses were performed using the Student's t-test. Differences were considered significant at $P < 0.05$. Means are compared using T-test at $P < 0.05\%$.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Fresh Duck Eggs, *Balut* and Salted Eggs

Nutritional quality is often associated with the amount of basic nutrients found in certain food products. Carbohydrate, fat and protein content in most food are used as indices whether certain food items are important sources of those particular nutrients. In general, eggs are known for its protein, fat and mineral content. However, it also contains other nutrients such as carbohydrate, free amino acids and vitamins.

Proximate composition of duck eggs are shown in Table 1. Ash content in food materials is often use as an index of the mineral content. Previous studies (Ahmad et al. 2017; Zhao et al., 2014; Ganesan et al., 2014) have reported ash content of duck eggs in both fresh and salted eggs. The amount of ash obtained ranged from 1.01-1.87%, these values were comparable to the ash content from duck eggs as reported by Ahmad et al. (2017).

Moisture content of *balut* (65.95 ± 0.06%) was significantly lower compared to fresh duck egg (72.19 ± 0.32%) and salted egg (72.74 ± 0.83). Moisture loss in *balut* can be attributed to the longer processing time (45mins) compared to salted eggs (25mins). Processing lowers the moisture content of duck eggs, a phenomenon, also observed in other food and agricultural products. Further, prolonged heat treatment causes slight shrinking of the contents of eggs. *Balut* is also found to contain higher amount of fiber (4.33 ± 0.28%) due to the partially developed feathers of the embryo. The presence of the

underdeveloped duck embryo is characteristic to fertile duck eggs incubated for about 16-18 days or even 20 days in other countries.

Processing alters the protein composition. This was observed in the amount of protein before and after processing of the duck eggs. In this study, duck eggs were found to be an extensive source of protein but the protein content of both *balut* and salted eggs used in this study decreased during processing. The values obtained ranged from 11.49 to 15.54 %, the latter was exhibited by the fresh duck eggs. These values were comparable to that reported by Dirwan-Muchlis and Nurcholis (2019). At the cellular level, high temperature increases the kinetic energy of protein molecules that leads to their denaturation and later to the formation of stronger covalent bonds with other protein molecules. The previously attached water molecules to the proteins are now released resulting in moisture loss and hardened egg contents. From 15.54 % ± 3.73 proteins in fresh eggs, only 11.89 ± 1.28% and 11.49 ± 2.29% for *balut* and salted eggs, respectively, were retained after processing. During protein degradation, proteins are broken down to their primary structures in the form of amino acids. Some amino acids form volatile compounds under alkali conditions which might have also transferred to the curing solution (Zhao et al., 2014), as in the case of salted eggs.

On the other hand, higher amounts of lipids are observed in salted eggs (10.15 ± 0.11%). Lipids in eggs exist as low-density lipoproteins (LDL) in the yolk plasma (Gilbert, 1971). During clay-curing, sodium chloride (NaCl) leads to dehydration and destruction of LDL structures. Some of the lipids of the cooked yolk become free (Lai et al., 1997) and contributed to the total fat obtained as shown in Table 1.

However, contrary to the results presented by Wang et al. (2014) that the fat content in eggs can be reduced to 0.61% by salting, this study showed that the fat content of the salted duck eggs had a significant increase in fat content compared to fresh duck egg and *balut*.

Table 1. Proximate composition of fresh, *balut,* and salted duck eggs.

Composition*, %	Fresh Egg	*Balut*	Salted Egg
Moisture	72.19 ± 0.32[a]	65.95 ±0.06[b]	72.74 ± 0.83[a]
Fat	4.49 ± 0.47[b]	4.01 ± 0.19[b]	10.15 ± 0.11[a]
Crude Fiber	2.42 ± 0.19	4.33 ± 0.28[a]	1.07 ± 1.11
Protein	15.54 ± 3.73[a]	11.89 ± 1.28[b]	11.49 ± 2.29[b]
Ash	1.28 ± 0.13	1.63 ± 0.42	1.01 ± 0.13

*Means with the same superscript are not significantly different from each other at P <0.05.

3.2 Mineral Composition of *Balut* and Salted Eggs

Table 2 shows the amount of trace minerals of fresh, *balut* or salted egg. Results indicated that processing into *balut* and salted egg does not significantly affect the amount of minerals found in duck eggs. In particular, magnesium (Mg), zinc (Zn), copper (Cu) and manganese (Mn), ranged from 0.16-0.24mg/100g, 0.04-0.06mg/100g, 0.01-0.11mg/100g and 2-4µg/100g, respectively. Results, further exhibited that iron (Fe), was present at higher concentration in *balut* (0.51mg/100g) compared to fresh duck and salted eggs. The iron content however, is lower than the amount reported by Ganesan et al. (2014). Potassium is mostly lost during cooking, as manifested by its low concentration in *balut* (1.85mg/100g). In the case of salted eggs, curing played an important role in the concentration of inorganic minerals. Significant amounts of K (4.57mg/100g), Na (13.28mg/100g), and Ca (4.07mg/100g) were observed for salted eggs as shown in Table 2. The clay-salt mixture provided a barrier to minimize mineral losses in duck eggs while allowing minerals from the mixture to penetrate the egg shell and migrate into the eggs. In general, the mineral content of the duck eggs used in this study were ten times lower compared to previous studies reported (Durwan Muchalis and Nuchalis, 2019; Ahmad et al., 2019; Ganesan et al., 2014).

Table 2. Mineral composition of duck eggs.

Minerals (mg/100g)*	Fresh Eggs	*Balut*	Salted Eggs
P	4.44 ± 0.36 [a]	4.92 ± 0.11 [a]	3.76 ± 0.01 [b]
K	3.92 ± 0.02 [b]	1.85 ± 0.02 [c]	4.57 ± 0.01 [a]
Na	5.04 ± 0.01 [b]	1.24 ± 0.05 [c]	13.28 ± 0.02 [a]
Ca	3.61 ± 0.00 [b]	3.47 ± 0.02 [b]	4.07 ± 0.01 [a]
Fe	0.14 ± 0.01 [b]	0.51± 0.02 [a]	0.10 ± 0.01 [b]
Mg	0.29 ± 0.01 [a]	0.16 ± 0.01 [a]	0.24 ± 0.01 [a]
Mn	0.002 ± 0.0006 [a]	-	0.004 [a]
Zn	0.04 [a]	0.06 [a]	0.04 [a]
Cu	0.01 [b]	0.01 [b]	0.11 ± 0.01[a]

*Means with the same superscript are not significantly different from each other at P <0.05.

3.3 Nutritional Value of *Balut* and Salted Eggs

Duck eggs weigh about 65 g on the average and provide 79-91 kcal based from the results presented in Table 3. Protein was found to provide 7-10g/65g or 4-10% of the recommended dietary allowance for adults (FNRI, 1997). This value means that duck eggs are considered as a good source of protein.

Additional recommendation of the Food and Nutrition Research institute (PDRI, 2015) for adult male 19-39 years of age, is to limit the sodium intake to <2 g and increase the intake of potassium to about 3, 510 mg in adult. Table 3 shows that salted eggs exhibited the highest sodium intake per serving which is estimated at 863 mg/65 g. Potassium, on the other hand, was computed at 297 mg/ 65 g of duck eggs. High salt content for salted egg is as expected because of the processing method used to produce these products. In related studies, salt content in salted eggs in general, ranged from 7-10% after curing for 15- 30 days (Wang, 2017).

However, the estimated cholesterol content of salted eggs is 202.00 mg as calculated based from a study conducted by Aziz et al. (2012). The cholesterol content of duck egg with 60 g average weight yolk

proportion is 186.46 mg. In the Nutritional Guidelines for the Prevention of Heart Diseases and Diabetes Mellitus (FNRI-DOST, 2002), it was stated that the dietary cholesterol should be less than 300 mg/day. With the estimated cholesterol content, duck egg already provides 67% of the recommended dietary cholesterol.

Therefore, inclusion of duck eggs, particularly salted eggs, should be done in moderation due to its big contribution to dietary cholesterol and minimal contribution to mineral intake.

Table 3. Composition (per serving size of 65g) of fresh and processed duck eggs.

Components	**Fresh Eggs**	***Balut***	**Salted Eggs**
Total Fat, g	3	3	7
Total Carbohydrates, g	3	8	2
Fiber, g	2	3	0.6
Protein, g	10	8	7
Calories, kcal	80	90	100
Na, mg	3.3	0.8	8.6
K, mg	2.5	1.2	3.0

3.4 Fatty Acid Composition of *Balut* and Salted Eggs

The amount of fatty acids is affected by the nutrients incorporated in the feeds given to ducks. Duck eggs are found to contain more unsaturated fatty acids than saturated ones. The major fatty acids in egg lipids are oleic, myristic and linoleic acids found in duck eggs from Victoria, Laguna, Philippines are shown in Table 4. Salted eggs had the highest amount of oleic acid (51.57%); *balut* has more myristic acid (26.30%). Linoleic acid is found to decrease after processing from 12.52% in fresh eggs to 10% in processed eggs (10.34% in *balut* and 10.04% in salted eggs). This is in contrast to that reported by Men et al. (2015)

wherein palmitoleic acid and linoleic acid took a greater proportion in the unsaturated free fatty acids, and their contents increased during the pickling period of salted duck eggs.

Myristic and lauric acid are strongly correlated with higher cholesterol levels (German & Dillard, 2010). Combined myristic and lauric acid for duck eggs range from 27.28 – 29.34%. This should be considered in the consumption and inclusion of duck eggs in the diet.

Table 4. Fatty acids in duck eggs as compared to coconut oil.

Fatty acid (% distribution)	**Fresh Egg**	**Salted egg**	***Balut***
C10:0	0.58	0.46	0.69
C12:0	2.29	4.24	1.58
C14:0	26.27	25.10	26.20
C16:0	2.15	1.31	0.59
C18:0	2.88	ND	3.62
C18:1	46.93	52.18	51.57
C18:2	12.52	10.34	10.04

4. CONCLUSION

Processing into salted eggs and *balut* has significantly affected the nutritional value of fresh duck eggs, including but not limited to their proximate composition and nutritional contents. Proteins, compared to other macronutrients, underwent the most biochemical and structural changes during processing. *Balut* and salted eggs provide more energy than fresh duck eggs based on the results of this study. Curing of eggs in clay-salt does not increase sodium levels in the salted eggs that could pose a health issues, however, consumption of these eggs must be done in moderation since they contain high levels of cholesterol.

ACKNOWLEDGMENTS

This study was conducted under the auspices of the Department of Science and Technology – Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (DOST-PCAARRD) under the program Philippine Duck Industry-Focused Technology, Innovations and Knowledge for Livelihood, Income and Food Supply Enhancement (ITIK for LIFE) Program, Project 3. Duck Egg and Meat Products Processing Innovations.

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2:00 PM - 2:15 PM (Wed. Sep 4, 2019 1:30 PM - 2:30 PM Room D)

[4-1330-D-03] Efficacy of 1-methylcyclopropene (1-MCP) Post-cutting Treatment on the Storage Quality of Fresh-cut ‘Queen’ Pineapple (Ananas comosus(L.) Merr. cv. ‘Queen’)

*Meryl Ancheta Bernardino[1], Katherine Anne Castillo Israel[1], Edralina Serrano[1], James Bryan Gandia[1], Wella Absulio[1] (1. University of the Philippines Los Banos(Philippines))

Keywords: visual quality rating, 1-MCP, ethylene suppresant, fresh-cuts, Queen pineapple

The efficacy of 1-methylcyclopropene (1-MCP) applied as a post-cutting treatment on freshcut ‘Queen’ pineapple was determined in order to assess its potential to maintain the storage quality of fresh-cut ‘Queen’ pineapple, a major Philippine variety. 1-MCP at a concentration of 1 uL• L -1 was applied as post-cutting treatment by injecting the gas into packed fresh-cut ‘Queen’ pineapples in polypropylene tray overwrapped with LDPE stretchable film. The packed fruits were stored at 5 oC and monitored for headspace gas concentrations (ethylene, CO2, O2), visual quality deterioration parameters and microbial deterioration indicators. 1-MCP was found to effectively elicit its ethylene inhibiting action as shown by lowered headspace ethylene by about 40% at day 4 storage. Headspace CO2 levels were likewise lowered by 1-MCP to about 50% at day 2 while higher headspace O2 levels were generally obtained which had the highest increase at day 2 (about 18%) which created an improved modified atmosphere condition inside the package compared with the control. No significant effects on the visual quality were noted throughout storage. Color differences were however observed, with 1-MCP treatments having significantly higher lightness values and higher hue values at day 2. 1-MCP did not affect the microbial growth (aerobic bacteria, acid-forming bacteria, yeasts and molds, coliforms) on the samples during storage. Aerobic bacteria count was slightly lower than the control at day 3. The fresh-cut pineapple packaged in the manner described had a shelf-life of 3 days based on the microbial limits set by EU countries which is log 7 cfu/mL aerobic plate count. To the best of our knowledge, this is the first study which demonstrated the effects of 1-MCP on fresh-cut pineapple of the ‘Queen’ variety.

2:15 PM - 2:30 PM (Wed. Sep 4, 2019 1:30 PM - 2:30 PM Room D)

[4-1330-D-04] Effect of Direct and Indirect Heating On Heat Stability of Goat Milk

*Souvia Rahimah[1] (1. Universitas Padjadjaran(Indonesia))

Keywords: goat milk, direct heating, indirect heating, heat stability

Goat milk is known to be generally less heat stable than cow milk. Two different genotypes of goat skim milk: Dahlem Cashmere (DC) and Saanen (SA) and cow milk as a reference, were subjected to three standard heating procedures under pilot plant conditions, using direct (steam injection) and indirect (tubular heat exchanger) techniques. Direct steam injection carried out under UHT conditions (140 °C, 0 s) with and without preheating treatment. Indirect heating procedures included high temperature-short time (HTST) pasteurisation (90 °C), extended short life (ESL) (120 °C) and ultra high temperature (UHT) (140 °C) treatments for 0, 60 and 120 s. The heated milks were analyzed with regard to the degree of whey protein denaturation (HPLC), casein micelles size (dynamic light scattering) and calcium content in serum (EDTA titration).

Analysis results indicated no severe difference between tube and pilot plant trials at 140 ˚ C for 0 s, except for casein micelle size, DC milk from pilot plant trials with preheating (90 ˚ C for 120 s) contained bigger particles.

Oral Session | Postharvest Facility

[4-1445-C] Postharvest Facility

Chair:Ahmad Al-Mallahi(Dalhousie University, Canada)

Wed. Sep 4, 2019 2:45 PM - 3:30 PM Room C (3rd room)

[4-1445-C-01] The Effect of Level of Fill on Nutritional Quality of Maize in an Un-aerated Clay Silos

*Mobolaji Omobowale[1], Jonathan Ogwumike[1] （1. University of Ibadan(Nigeria)）

2:45 PM - 3:00 PM

[4-1445-C-02] Pod Storage and Maturity Effects on Specialty Cacao Pulp Quality

*Jeana Cadby[1], Tetsuya Araki[1], Ian Marc Cabugsa[2] （1. University of Tokyo, Dept. Global Agricultural Sciences(Japan), 2. Ateneo de Davao University, Dept. of Chemistry(Philippines)）

3:00 PM - 3:15 PM

[4-1445-C-03] Current Status of Monitoring Post-Harvest Potato Storage Units in Atlantic Canada

*Ahmad Al-Mallahi[1] （1. Dalhousie University(Canada)）

3:15 PM - 3:30 PM

2:45 PM - 3:00 PM (Wed. Sep 4, 2019 2:45 PM - 3:30 PM Room C)

[4-1445-C-01] The Effect of Level of Fill on Nutritional Quality of Maize in an Un-aerated Clay Silos

*Mobolaji Omobowale[1], Jonathan Ogwumike[1] (1. University of Ibadan(Nigeria))
Keywords: Clay Silo, Grain Quality, Postharvest losses, Maize, Level of Fill

Silos have a fixed volume at the time of construction; harvests however vary from season to season. Arising from complaints of severe postharvest losses in grains, most especially in the humid tropics of southern Nigeria, this study investigated the effect of level of filling on the nutritional quality of stored maize. Three clay silos labelled S_1 to S_3 of the same dimension and capacity (3.5 metric tonnes) were used. The walls were painted externally with gloss paint to eliminate or reduce water absorption into the silos. The three silos were filled with shelled maize; with the first silo (S_1) was filled with 3 tonnes, the second silo (S_2) was filled with 2 tonnes while the third silo (S_3) was filled with a tonne of maize. A storage experiment was carried out for 6 months and data was collected on environmental conditions within the silo as well as grain quality with increasing time of storage. Temperature, relative humidity and equilibrium moisture content were obtained three times daily for each of the three silos, focusing on the air-space between the grains and the head-space above the grains. Temperature fluctuations within the fully filled S_1 as indicated by the statistical range of 2^o C was minimal compared with that of S_2 and S3 at 7 and 8^{o}C respectively. Silo S_3 showed high values of relative humidity toward the end of storage period, ranging between 65% to 80% at the top level and 76% at the bottom level. Equilibrium moisture content at the airspace above the grains in S_1 increased from 12.0% at the beginning of storage in the dry season to 15.6% at the end of storage in the rainy season compared with S_2 and S_3 which increased from 12.0 to 17% and 12.0 to 17.2% respectively within the same period. Fungal and total viable counts showed an increase in microbial activity with decreasing level of fill. Grains were found to be more prone to deterioration with decreasing level of fill and recommendations were made to farmers and grain traders on proper actions to take as the situation arises.

3:00 PM - 3:15 PM (Wed. Sep 4, 2019 2:45 PM - 3:30 PM Room C)

[4-1445-C-02] Pod Storage and Maturity Effects on Specialty Cacao Pulp Quality

*Jeana Cadby[1], Tetsuya Araki[1], Ian Marc Cabugsa[2] (1. University of Tokyo, Dept. Global Agricultural Sciences(Japan), 2. Ateneo de Davao University, Dept. of Chemistry(Philippines))
Keywords: pod storage, post harvest quality, Theobroma cacao, specialty cacao

The quality of the cacao fruit pulp surrounding the seeds plays an important role in the early stages of post harvest processing, namely fermentation, influencing final cacao quality for specialty cacao products. Pod storage is common in cacao production, and has also been cited as a technique used by bulk/commodity cacao producers as a way to reduce undesirable acidity in cacao. However, longer storage periods are also associated with continued development or introduction of disease and contaminants that are highly undesirable in specialty cacao, and likely to be noticeable in the final product.Two post harvest treatments on measurements of brix, pH, pod weight, and seed with pulp weight in the pre-fermentation, early post-harvest processing stage were investigated, including cacao pods under storage treatments as well as separated by maturity under storage treatments. Fresh and over ripe fruits displayed the highest brix (17.53 average and 15.97 average, respectively) and overripe fruits with longer storage periods displayed the lowest (12.6 and 13.61, average respectively). Significant losses in brix, pod weight, and seed with pulp weight were

observed, and pH also significantly changed with storage treatments and ripeness. Post harvest treatments of pod storage and pod maturity significantly impact the pulp quality in early stages cacao processing, potentially influencing final cacao quality. When treatments are applied in order to reduce pulp acidity, shorter storage times appear to be equally effective in reducing pulp acidity, while also shortening the window for contamination and off flavor development. The relationship between pod maturity and pulp acidity begs further investigation for similar objectives.

3:15 PM - 3:30 PM (Wed. Sep 4, 2019 2:45 PM - 3:30 PM Room C)

[4-1445-C-03] Current Status of Monitoring Post-Harvest Potato Storage Units in Atlantic Canada

*Ahmad Al-Mallahi[1] (1. Dalhousie University(Canada))

Keywords: Storage Unit, Montioring System, Environmental Sensors, Potato tuber, Disease control

Potato is the largest crop in Atlantic Canada producing nearly one-third of the national share. Potato production in this region is characterized by short growing season and long storage periods where most of the produce destined for processing. Farmers, in this region, tend to have their own storage units where they pile in their yield immediately after the short harvesting season, while they gradually dispatch batches of their yield upon requests from processing factories. Storage lasts from autumn, through the harsh Canadian winter, until early summer during which farmers have to manage the storage units to keep their potatoes as fresh as possible and to avoid any spread of damage such as rots or other disease. The most common parameters to be monitored in a storage unit are temperature, relative humidity, and carbon dioxide concentration. These parameters control ventilation mechanism that pass air in underground ducts and through the potato pile. A mechanism of humidifying the air is occasionally actuated to increase humidity in the ventilating air to avoid tubers dehydration. Generally, the temperature is kept as low as 9 ℃ while the humidity is raised to as high as 95% to maintain optimum conditions. While sensors within the pile are usually used to monitor temperature, humidity sensors cannot sustain the storage conditions for one whole season. Therefore, farmers rely on portable sensors to measure humidity manually in a low frequency. Similarly, portable sensors are occasionally brought in to measure carbon dioxide concentrations which can be an indicator of disease breakout. Based on the current storage monitoring situation, temperature is fairly controlled by automatic temperature sensing and ventilators actuation, whereas humidity is controlled based on regular actuation of the humidification system and occasional review of the humidity levels. This situation can still cause misjudgment not only because of the low frequency of monitoring humidity but also the bias of measuring certain spots of temperature where the sensors are located. Since losing potatoes in the storage unit can be economically harmful, it is important to improve the current monitoring techniques to maintain potatoes fresh and minimize probability of disease breakout. In our research group at Dalhousie University, we are setting up a comprehensive plan to tackle problems associated with monitoring potato storage units. Our plan will include digging deep to find root causes of humidity sensor failure under storage conditions to develop more robust sensors. Also, we will rely on state-of-the-art technology of wireless sensing to have better understanding of the distribution of the parameters within the storage unit. These developments aim not only to improve the storage conditions but also to serve as early detection systems of disease breakouts. Considering the vast area that needs to be covered to collect data from different storage units scattered at different locations, we plan to develop remote data collection system to enable fast collection of information and centralized big data base for the region. The goal of big data analysis will be to find trends among the disconnected storage units and determine locations at higher risk of yield loss during storage.

Oral Session | Postharvest Machinery

[4-1445-D] Postharvest Machinery

Chair:Yukiharu Ogawa(Chiba University, Japan)

Wed. Sep 4, 2019 2:45 PM - 3:15 PM Room D (4th room)

[4-1445-D-01] A Numerical Procedure for Supporting Garlic Root Trimming Machines Using Deep Learning Algorithms

*Thuyet Quoc Dang[1], Morinobu Matsuo[1,2], Takeshi Haji[1], Tetsuo Kawaide[1], Yuichi Kobayashi[1] （1. Institute of Agricultural Machinery, National Agriculture and Food Research Organization(Japan), 2. Central Region Agricultural Research Center, National Agriculture and Food Research Organization(Japan)）

2:45 PM - 3:00 PM

[4-1445-D-02] A Nondestructive Acoustic Vibration System for Apple Firmness Assessment

*Chengqiao Ding[1], Di Cui[1] （1. Zhejiang University(China)）

3:00 PM - 3:15 PM

2:45 PM - 3:00 PM (Wed. Sep 4, 2019 2:45 PM - 3:15 PM Room D)

[4-1445-D-01] A Numerical Procedure for Supporting Garlic Root Trimming Machines Using Deep Learning Algorithms

*Thuyet Quoc Dang[1], Morinobu Matsuo[1,2], Takeshi Haji[1], Tetsuo Kawaide[1], Yuichi Kobayashi[1] (1. Institute of Agricultural Machinery, National Agriculture and Food Research Organization(Japan), 2. Central Region Agricultural Research Center, National Agriculture and Food Research Organization(Japan))

Keywords: Garlic, Root trimming, Deep learning, Convolutional neural networks, Computer vision

Smart agricultural machinery is indispensable for modern postharvest processes for reducing human labor force, safety and increasing productivity. This study introduces a method to detect and evaluate the root trimming condition of garlics based on garlic images or the live streaming video from a personal computer webcam using convolutional neural network algorithms. This was an artificial intelligence system utilizing transfer learning techniques in deep learning. We aimed to develop a real-time classification system of garlic during the root trimming process and to provide signals to autonomously control a garlic trimming machine. The classification considered as three classes namely, good, bad and scratch. The good class consisted of successfully trimmed garlics whereas the bad class consisted of incompletely trimmed garlics which required further trimming. The scratch class consisted of defective garlics that should be removed during garlic postharvest processes. The classification system was automatically operated when a garlic was placed under the webcam. The analysis results were sent to two replays via serial ports for further automation processes. It effectively classified images for root trimming. The classification was instant, and its accuracy was about 96%. The signal can be used to develop an unmanned trimming machine. This system has the potential for high-impact applications in agricultural imaging, especially in postharvest machinery.

Oral Session | Postharvest Machinery
[4-1445-D] Postharvest Machinery
Wed. Sep 4, 2019 2:45 PM - 3:15 PM Room D (4th room)

[4-1445-D-02] A Nondestructive Acoustic Vibration System for Apple Firmness Assessment

*Chengqiao Ding[1], Di Cui[1] (1. Zhejiang University(China))

Keywords: Fruit firmness, Excitation device, Test parameters, Vibration characteristics

Fruit firmness is closely related to the physical structures and mechanical properties, which is an important index at different stages of the food supply chain. In this paper, a loudspeaker-based excitation device was designed and compared with the traditional vibration shaker. The apples were placed on a string bag and driven by the swept sine wave signals ranging from 50 to 2000 Hz. And the response signal of apples was acquired by a laser doppler vibrometer (LDV) which was hung on the top of the excitation units. The test parameters of detection system were optimized in the single factor experiment, and the superior combination of test parameters were as follows: the aperture of sound source was 40 mm, the distance between fruit surface and loudspeaker was 95 mm, and the posture style was that the apple was placed with its stem upward. After the optimization of detection system, six vibration characteristics were extracted from the frequency response function (FRF) to establish the relationship with fruit firmness obtained by the puncture test. The correlation results showed the stiffness of apples was closely related to elasticity index (*EI*) and stiffness coefficient (*SC*), which was considered as a dependent variable in different regression models. Furthermore, the highest correlation coefficient r_p of the prediction set was observed in the BP neural network model by using *EI*, the peak value at f_2 and the peak area as the independent variables (r_p=0.914, RMSEP=0.561 N mm^{-1}).

A Nondestructive Acoustic Vibration System for Apple Firmness Assessment

Chengqiao Ding[1], Di Cui[1]*
[1]College of Biosystems Engineering and Food Science, Zhejiang University, P. R. China
* Corresponding author: dicui@zju.edu.cn

ABSTRACT

Fruit firmness is closely related to the physical structures and mechanical properties, which is an important index at different stages of the food supply chain. In this paper, a loudspeaker-based excitation device was designed and compared with the traditional vibration shaker. The apples were placed on a string bag and driven by the swept sine wave signals ranging from 50 to 2000 Hz. And the response signal of apples was acquired by a laser doppler vibrometer (LDV) which was hung on the top of the excitation units. The test parameters of detection system were optimized in the single factor experiment, and the superior combination of test parameters were as follows: the aperture of sound source was 40 mm, the distance between fruit surface and loudspeaker was 95 mm, and the posture style was that the apple was placed with its stem upward. After the optimization of detection system, six vibration characteristics were extracted from the frequency response function (FRF) to establish the relationship with fruit firmness obtained by the puncture test. The correlation results showed the stiffness of apples was closely related to elasticity index (*EI*) and stiffness coefficient (*SC*), which was considered as a dependent variable in different regression models. Furthermore, the highest correlation coefficient r_p of the prediction set was observed in the BP neural network model by using *EI*, the peak value at f_2 and the peak area as the independent variables (r_p=0.914, RMSEP=0.561 N mm^{-1}).

Keywords: Fruit firmness Excitation device Test parameters Vibration characteristics

1. INTRODUCTION

With the increasing requirement for high-quality fruits, fruit classification and detection are becoming more and more important, which are based on both external and internal quality. External quality indicators mainly contain color, shape, size and appearance quality, while internal quality indicators mainly include chemical compositions (sugar, acidity, vitamin content, inorganic salt, ester, ethylene, etc.), texture and defects. As for the apple, firmness is widely used for its texture or ripeness evaluation, which is closely related to the physical structures and mechanical properties (Li et al., 2011; Pozrl et al., 2010). Accurate detection of firmness is indispensable in fruit supply chain. At harvest stage, firmness is utilized to determine the optimal harvest time and ripeness for edibility. In the grading process, firmness is the basis for classification. In the transportation, firmness is regard as a standard to select proper methods of transportation and packaging. During the storage, firmness helps to confirm storage temperature, humidity and time. As for the sale stage, firmness is used to assess the shelf-life and freshness, which deeply affect consumer purchase behaviors (Zhang et al., 2015). Fruit firmness detection methods can be divided into two classes, including destructive and nondestructive methods. The widely used destructive methods are the Magness-Taylor puncture test, which was deemed to be an industry standard. In the puncture test, a penetrometer records the force-deformation (F/D) curve by penetrating fruit tissue at a certain speed and extracts firmness indexes of fruit flesh based on F-D curve (Camps et al., 2005). However, destructive

methods are time-consuming, labor-intensive and local measurement. Thus, many nondestructive techniques have been developed for firmness assessment, such as acoustic vibration (Taniwaki and Sakurai, 2010), spectroscopy (Xing et al., 2006), ultrasonic (Mizrach and Flitsanov, 1999), etc. Among them, acoustic vibration method was commonly used in practice use, since it provides direct measurement of the mechanical and physical properties (García-Ramos et al., 2005; Grotte et al., 2002). Based on existing researches, a series of vibration characteristics were extracted to evaluate the fruit firmness, such as f^2m, $f^2m^{2/3}$ and $f^2m^{2/3}\rho^{1/3}$ (Abbott et al., 1992; Duprat et al., 1997; Schotte et al., 1999). To obtain the acoustic vibration characteristics, many measurement methods and experimental apparatuses were developed (Taniwaki and Sakurai, 2010). In order to not influence the original vibration of the sample, noncontact excitation devices and detection sensors were introduced to nondestructive measurement, such as the loudspeaker and the laser Doppler vibrometer (LDV). Muramatsu et al. (1996) used a small speaker to emit sound wave with frequencies from 200 to 2000 Hz to excite the fruits by an oscillator, and the response signal was acquired by a microphone on the opposite side. Similarly, Kataoka et al. (2016) developed a portable device to detect tomato firmness, which consisted of a smart phone, a microphone and speaker. The smart phone provided the swept sine signal from 20 to 10000 Hz in 1 s to excite fruit by speaker and captured the response signal by a microphone. Besides, the LDV is another alternative non-contact sensor to obtain the vibration velocity of the samples based on the Doppler shift of the laser beam frequency for its merits of noninterference movement, high spatial resolution, high precision and large measuring range (Murayama et al., 2006). In the early time, Muramatsu et al. (1997) applied the LDV system to monitor the firmness of apples, kiwifruits and pears. The results showed that vibration spectrum received by a laser doppler vibrometer had higher precision than the accelerometer method, especially in the frequency band from 800 to 1600 Hz. Lately, Abbaszadeh et al. (2013) developed a LDV system to estimate the firmness of watermelon. In the detection, the watermelon with a reflective film was excited by a mechanical shaker, and the vibration response signal was recorded by the LDV. The results showed that the prediction of stepwise multiple linear regression model (SMLR) based on phase spectrum was better than partial least squares regression model, and the determination coefficient of validation set was 0.9986.

The objectives of this research were to: (i) develop a loudspeaker-based excitation device and compare detection results with the traditional vibration shaker; (ii) to investigate the optimal test parameters in the single-factor experiment, including apple posture style, the aperture of sound source, and the distance between fruit surface and loudspeaker; (iii) to establish the relationships between apple firmness and vibration parameters in different regression models.

2. MATERIALS AND METHODS

2.1 Samples

'Fuji' apples (*Malus domestica* cv. Fuji, produced in Shanxi province, China) were purchased from the local fruit orchard, which has round shape, firm and juicy flesh, rich nutrition ingredients and good storage ability. A total of 48 apples with uniform size and spherical shape were selected and stored in the laboratory at 20 ℃ and 60 %RH. Before the test, each sample was placed at room temperature for 12 h and randomly coded. Then the morphological properties of each sample were measured three times, and average values were calculated for

analyses, including the mass (m), height (h) and equator diameter (d). After that, the vibration response signals and the firmness of samples were acquired by the following tests.

2.2 Vibration Response Signal Measurement

The design of the vibration measurement systems was shown in Fig.1, which was similar to the detection system used by Zhang et al. (2014) and Cui et al. (2015) (Fig.2). The system was mainly consisted of a loudspeaker (CS622C, Dayton Enterprises, USA), a microphone (40AE, M+P Enterprises, Germany), a LDV equipment (LV-S01, Sunny Instruments Singapore Pte., Ltd., Singapore), the NI data acquisition unit (USB-4431, National Instrument, Austin, USA), a power amplifier and a PC. In the measurement, the apple with a reflective film was placed on the string bag to vibrate freely. And the loudspeaker produced the swept sine wave signal (frequency range from 100 to 200 Hz in 1 s) to stimulate the apple. The sound signal was recorded by the microphone as the input signal (X_{in}). In the meantime, the LDV was used to acquire the vibration response signal from the fruit surface, which was regard as output signal (X_{out}). These two signals were changed from the time domain to the frequency domain based on Fast Fourier Transform (FFT), and the ratio was the frequency response function (FRF) (Fig.3). Then some vibration characteristics were extracted from FRF, such as the peak value (A), the second resonant frequency (f_2), the peak width at half height (w) and peak area ($S=Aw$).

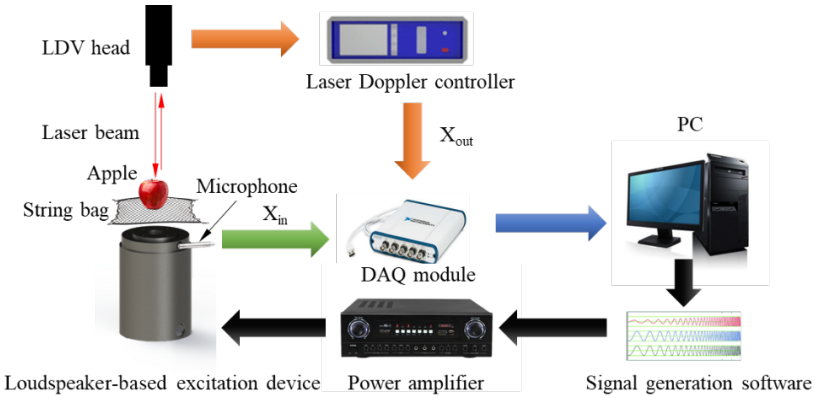

Figure 1. A loudspeaker-based LDV detection system.

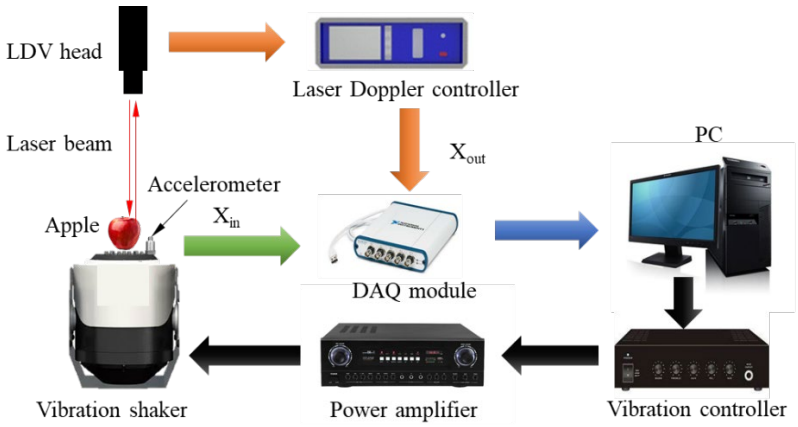

Figure 2. A vibration generator-based LDV detection system.

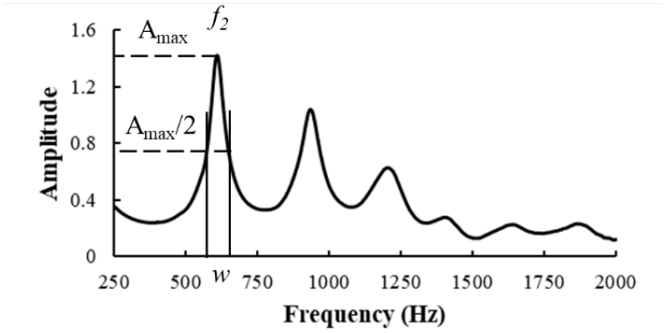

Figure 3. The typical FRF obtained from an apple by the acoustic vibration system.

2.3 Firmness Measurement

The firmness of apples was destructively measured by a standard penetrometer (TA-XT2i, Stable Micro Systems Ltd., England). In this study, three peeled detection points with equal intervals on the equator of the apple were selected. At each site, a flat-tip cylindrical probe (P/5) with a diameter of 5 mm was inserted into the sample. The penetration velocity and depth were 1 mm s^{-1} and 8 mm, respectively. Three firmness indexes were extracted from the force/deformation (F/D) curve, including stiffness (*Stif*, the slope of curve before the rupture point), *MT* firmness (the maximum force) and flesh firmness (*FF*, the mean force at a distance of 2–8 mm) (Fig.4). The average values of each firmness index were calculated and used for following analyses.

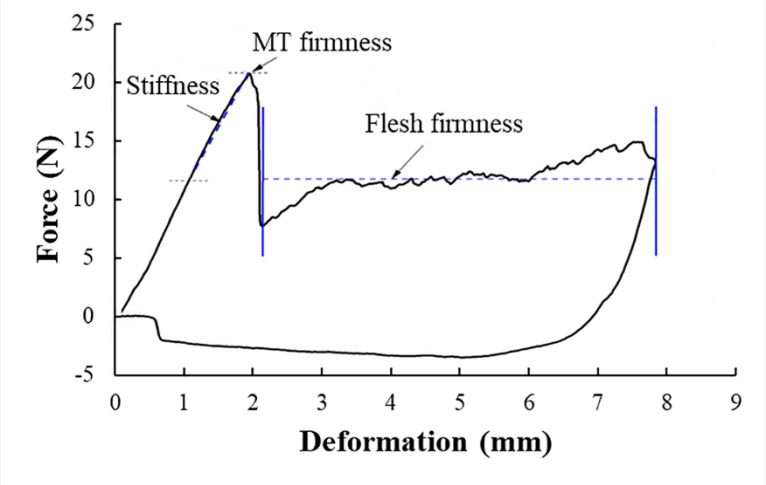

Figure 4. A representative force–deformation curve obtained from the puncture test.

2.4 Statistical Analysis

Correlation analysis was utilized to understand the direction and strength of the relationship between 2 individual variables (Cliff and Bejaei, 2018). In this study, the relationships among the firmness indexes extracted from force/deformation (F/D) curves and vibration characteristics obtained from FRF were assessed with values of the correlation coefficient (*r*), which were calculated through the Eq. (1).

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2 \cdot \sum_{i=1}^{n}(y_i-\bar{y})^2}} \quad (1)$$

where x_i and y_i are nth measurements of variables X and Y (i=1,2, … , n), and $\bar{x}$ and $\bar{y}$ are the mean values of X and Y.

The repeatability of the vibration parameters was evaluated by coefficient of variation (CV), which was ratio of standard deviation (SD) of repeated measurements and their mean values (Mean). In the study, the value of CV below 10% showed that the detection system had a good repeatability (Wen et al., 2015).

Stepwise multiple linear regression (SMLR) method was a method to select significant independent variables and remove those that are not important based on the variance contribution in a linear regression model to avoid multicollinearity (Wang and Xie, 2014).

The partial least squares regression (PLSR) method was used to diminish the influence of high linear correlation between independent variables. In this study, the PLSR model was established with vibration characteristics from 48 apples. There were 32 and 16 samples in calibration and validation sets, respectively.

Support vector regression (SVR) was a supervised learning method which could be used for nonlinear regression analysis. The main characteristics of this method was to maintain the maximal margin and minimize the error (Liu et al., 2014).

Back propagation neural network (BPNN) was a multi-layer feedforward network trained by error inverse propagation algorithm, which was a supervised learning model. A neural network mainly consists of three parts: input layer, hidden layers, and output layer. Each layer had several neurons which was connected with other layers. The main characteristics were forward signal transmission and error back propagation. In the process of calculation, this method would adjust the network weights and threshold according to the prediction error until the result was close to the desired output (Liu et al., 2010).

3. RESULTS AND DISCUSSION

3.1 Physical Properties of Apples

Forty-eight fresh apples were selected with uniform size and shape in local orchard. The mean values and SD of the physical parameters such as mass, height, and equator diameter of test samples were presented in Table 1. It was revealed that the variations of these parameters were less, which indicated that the differences in their appearance were limited.

Table 1. Physical properties of experimental apples (n=48). (SD: Standard deviation)

Physical parameters	Mass (g)	Height (mm)	Equator diameter (mm)
Mean ± SD	280.06±31.41	79.47±4.28	74.53±3.78

3.2 Comparison of Contact and Noncontact Type Excitation Methods

The loudspeaker was used as a noncontact type device to excite the apple which was placed on a string bag, while the shaker was regard as a contact type device in excitation. The differences in performances of these two devices were compared based on the second resonant frequency (f_2) of 12 apples. Each measurement was repeated three times, and the deviation ratios (D) were utilized to describe the degree of the difference (Fig.5), which were calculated by the Eq. (2). The results showed that the f_2 obtained by shaker-based method was little higher than the

loudspeaker-based method. Due to the low values of deviation ratio, it was indicated that there was no significant difference in the second resonant frequency detection by these two excitation methods. However, the intensity of sound wave was relatively low, which may cause the insufficient excitation for large fruit.

$$D = \frac{f_2 - f_2'}{f_2} \quad (2)$$

where f_2 and f_2' were the second frequencies obtained by shaker-based method and loudspeaker-based method, respectively.

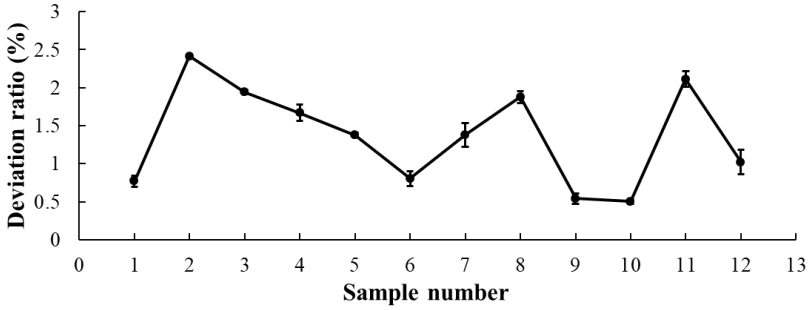

Figure 5. Deviation of the second resonant frequencies of the apple. The bars represent the standard error.

3.3 Repeatability of Vibration Parameters

The repeatability of vibration parameters was represented by the coefficient of variation (CV) of 12 apples (Fig.6). The results showed that the second frequency had the lowest CV value than other indexes. Besides, the peak value had better repeatability than the peak width at half height and the peak area. The CV values of all indexes were less than 10 %, which indicated that the loudspeaker was suitable for excitation in the detection.

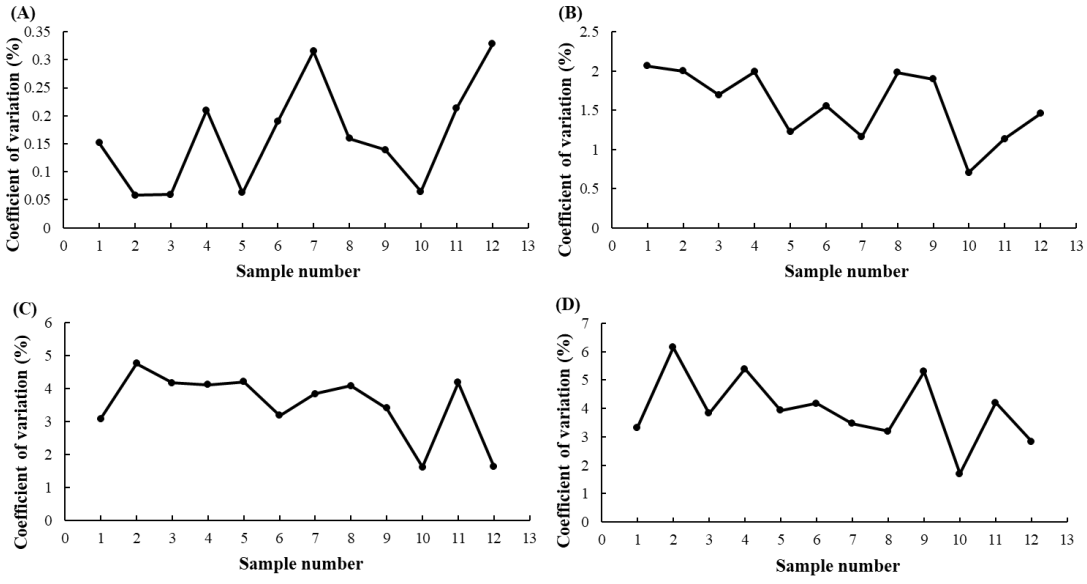

Figure 6. The coefficient of variation of the second resonant frequency (A), the peak value

(B), the peak width at half height (C) and the peak area (D).

3.4 Effects of Test Parameters on Vibration Signal

3.4.1 Different structural parameters

The schematic diagram of the loudspeaker-based excitation device was shown in Fig.7. In general, the intensity of the sound wave was closely related to the diameter of gasket and the distance between fruit surface and loudspeaker. In this section, the signal-to-noise ratio (SNR) was used to evaluate the performance of different structural parameters by single factor experiment.

Figure 7. The schematic diagram of the loudspeaker-based excitation device. (d: the diameter of gasket; h: the distance between fruit surface and loudspeaker)

The three sizes of gaskets were designed in this study, including 20 mm, 30 mm and 40 mm (Fig.8). The SNR values at different diameters of gaskets were shown in Fig.9. It was revealed that the 40 mm gasket obtained the largest SNR value, and there was no significant difference in the other two groups.

Figure 8. The different sizes of gaskets.

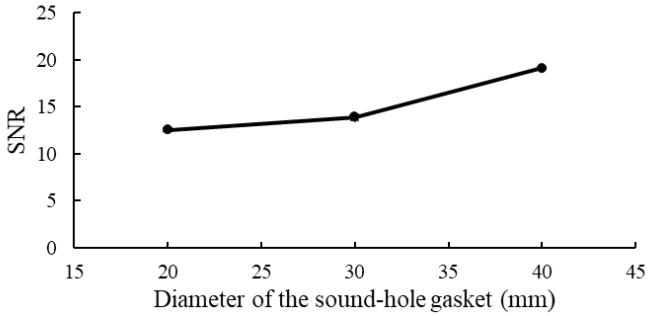

Figure 9. The SNR values of different sizes of gaskets.

The distance between fruit surface and loudspeaker could be adjusted from 95 mm to 155 mm. The SNR values at different distances were shown in Fig.10. The results showed that there was a nearly linear relationship between the SNR values and the distances. And the 95 mm group was found to have the maximum SNR value than other groups. Thus, the optimum size of the gasket and the distance were 40 mm and 95 mm, respectively.

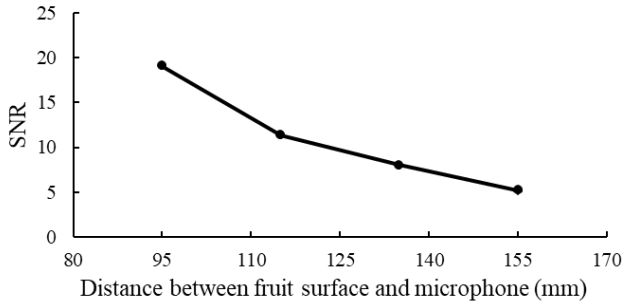

Figure 10. The SNR values of different distances between fruit surface and loudspeaker.

3.4.2 Different Detection Points and Posture Styles

The apple could be placed on the string bag in three different posture styles (Fig.11). In order to evaluate the repeatability of vibration parameters at each posture style, three detection points with equal intervals were selected as a group to compare. The performances of repeatability were represented by CV values (Fig.12). Good repeatability was found in each group of detection points (CV<5%), which indicated that there was no significant difference in different detection points at each posture styles. Besides, posture style B had high CV values in both resonant frequency and peak value.

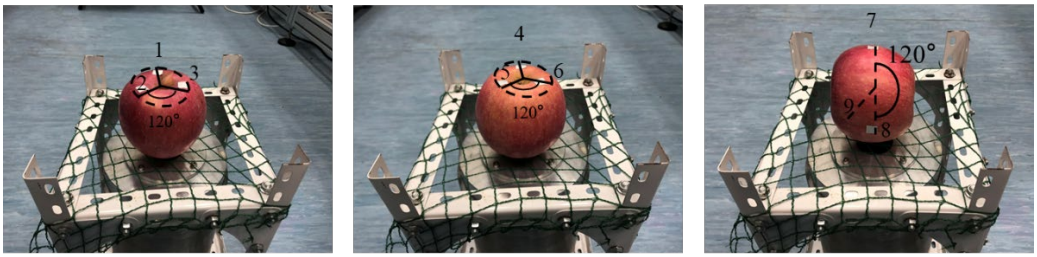

Figure 11. Different detection points and posture styles in detection system. A: the apple stem is upward; B: the apple calyx is upward; C: the apple stem-calyx is horizontal.

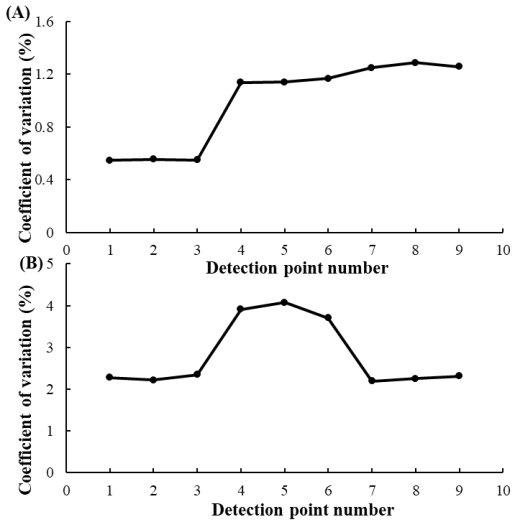

Figure 12. The coefficient of variation of resonant frequency (A), the peak value (B) in different detection points.

Fig.13 showed the SNR values at different posture styles. In general, the posture style A obtained the little higher SNR value than the posture style B. Besides, posture style C had lowest SNR value, which may be caused by unstable placements. Due to the biggest standard error at the posture style B, the posture style A was considered better and selected for the subsequent experiments.

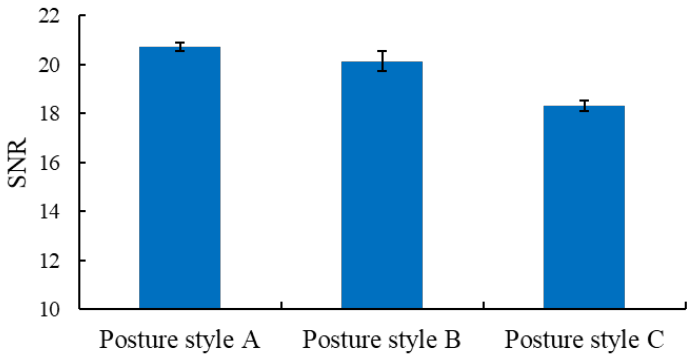

Figure 13. The SNR values of three posture styles. The bars represent the standard error.

3.5 Quantitative Analysis of Apple Firmness

After verification of the optimum test parameters, the vibration response signals of 48 apples were acquired. Four vibration characteristics were extracted from FRF, such as the peak value (A), the second resonant frequency (f_2), the peak width at half height (w) and peak area (S=Aw). Then elasticity index (EI=$f_2^2 m^{2/3}$) and stiffness coefficient (SC=$f_2^2 m$) were calculated to investigate the relationship with fruit firmness. In order to diminish the collinearity effect of these indexes on regression models, the inter-correlations of six variables were represented in Table 2. The results of correlation analysis demonstrated that the cross-correlations among the second resonant frequency, elasticity index (EI) and stiffness coefficient (SC) were closely correlated ($p \leq 0.01$), with r values between 0.484 and 0.827 (n = 48). Besides, w was strongly correlated with S (r = 0.771), EI (r = -0.611) and SC (r = -0.641). S was moderately correlated with A (r = 0.544), EI (r = -0.459) and SC (r = -0.446). The results also indicated that A was slightly correlated with the other four variables (r = -0.075 to -0.250), except S. Strong relationships among the independent variables would lead to the multicollinearity problem in the regression models. Thus, it was necessary to choose appropriate variables to improve the prediction of models. Due to the previous researches, the resonance frequency would be influenced by the object size. Thus, EI and SC were used to compensate for the difference in fruit size (Abbott et al., 1968; Cooke, 1972). In addition, f_2 and w would not be introduced as independent variables in the multiple regression model.

Table 2. Correlation coefficients (r) among vibration characteristics (n = 48).

Variable	f_2	A	w	S	EI	SC
f_2	1					
A	-0.307	1				
w	-0.075	-0.094	1			
S	-0.221	0.544*	0.771*	1		
EI	0.484**	-0.250	-0.611**	-0.499*	1	
SC	0.529**	-0.087	-0.641**	-0.446*	0.827**	1

Asterisks indicate statistical significance: ** significant correlation at the level of 0.01; *significant correlation at the level of 0.05.

The correlations between the firmness indexes obtained by the puncture test and vibration characteristics (EI and SC) were showed in Table 3. The results revealed that stiffness had the highest correlation with EI and SC, which was regard as a dependent variable in regression models.

Table 3. Correlation coefficients (r) among vibration characteristics and firmness indexes.

Variable	$Stif$	MT	FF
EI	0.852**	0.534*	0.222
SC	0.629**	0.434*	0.242

Asterisks indicate statistical significance: ** significant correlation at the level of 0.01; *significant correlation at the level of 0.05.

The results of the unary linear regression models were showed in Table 4. All factors (*EI*, *SC*, f_2, *w*, *S*), except *A*, were strongly correlated with fruit stiffness. The best unary regression model for prediction of stiffness was established by using *EI* as an independent variable, whose r_p and RMSEP of prediction set were 0.830 and 0.770, respectively.

Table 4. Statistical results of the unary linear regression models for determining stiffness of apples.

Factors	Regression model	Calibration set		Prediction set	
		r_c	RMSEC	r_p	RMSEP
EI	$y= 4.643\times10^{-5}x+2.768$, F=48.824 (**$P$<0.01)	0.894	0.556	0.830	0.770
SC	$y= 3.961\times10^{-5}x+7.740$, F=13.090 (**$P$<0.01)	0.694	0.628	0.611	1.094
f_2	$y= 0.010x+5.837$, F=8.016 (**P<0.01)	0.556	0.487	0.517	1.182
A	$y= -69.934x+15.082$, F=1.011 (P > 0.05)	0.226	1.198	0.210	1.351
w	$y= -0.031x+16.769$, F=11.078 (**P<0.01)	0.573	0.738	0.579	1.126
S	$y= -1.373x+16.295$, F=12.149 (**P<0.01)	0.745	0.540	0.597	1.109

Asterisks indicate statistical significance: ** significant correlation at the level of 0.01; *significant correlation at the level of 0.05.

In order to diminish the collinearity effect of vibration characteristics on a multiple linear regression model, stepwise multiple linear regression (SMLR) was utilized to variable selection. The performances of SMLR models were showed in Table 5. It could be seen that using *EI*, the peak value and the peak area could obtain the better prediction result than another model, and the r_p and RMSEP of prediction set were 0.871 and 0.712 N mm^{-1}, respectively.

Table 5. Statistical results of SMLR model for determining stiffness of the apples.

(I)

Factors	Regression coefficient	Calibration set		Prediction set	
		r_c	RMSEC	r_p	RMSEP
EI	4.042×10^{-5}	0.909	0.474	0.871	0.712
A	22.145				
S	-0.0472				
Constant	4.643				
F=16.210, **P<0.01					

(II)

Factors	Regression coefficient	Calibration set		Prediction set	
		r_c	RMSEC	r_p	RMSEP
SC	2.601×10^{-5}	0.795	0.600	0.701	1.044
A	9.716				
S	-0.934				
Constant	11.352				
F=6.173, **P<0.01					

Asterisks indicate statistical significance: ** significant correlation at the level of 0.01; *significant correlation at the level of 0.05.

The performances of different nonlinear models for prediction of stiffness were represented in Table.6. Compared with the results of the unary linear regression model, PLSR and BP neural network model had the better prediction ability. Besides, SVR model was the worst in calibration set and prediction set. Furthermore, the highest correlation coefficient r_p of the prediction set was obtained in the BP neural network method by using *EI*, *A* and *S* as independent variables (r_p = 0.914, RMSEP = 0.561 N mm^{-1}).

Table 6. Results of quantitative analysis of stiffness by different nonlinear models.

Modeling method	Input variables	Calibration set		Prediction set	
		r_c	RMSEC	r_p	RMSEP
PLSR	*EI*, *A* and *S*	0.904	0.557	0.842	0.754
	SC, *A* and *S*	0.727	0.949	0.688	1.089
SVR	*EI*, *A* and *S*	0.893	0.519	0.801	0.671
	SC, *A* and *S*	0.699	0.627	0.568	0.994
BP neural network	*EI*, *A* and *S*	0.957	0.413	0.914	0.561
	SC, *A* and *S*	0.889	0.617	0.858	0.805

4. CONCLUSION

The loudspeaker-based excitation device was designed and used in the LDV detection system. The test parameters of detection system were optimized based on the results of CV values and SNR values under different test conditions. A better combination of test parameters for vibration response signal measurement were as follows: the aperture of sound source was 40 mm, the distance between fruit surface and loudspeaker was 95 mm, and posture style was that the apple was placed with its stem upward. Based on optimized system, the vibration responses of 'Fuji' apples were acquired, and then six vibration characteristics were extracted, including the peak value, the second resonant frequency, the peak width at half height, peak area, *EI* and *SC*. The correlations between the firmness indexes obtained by the puncture test and vibration characteristics (*EI* and *SC*) were revealed that stiffness had better performance than other firmness indexes, which was regard as a dependent variable in different regression models. Moreover, the best prediction of firmness was observed in the BP neural network model by using *EI*, *A* and *S* as input variables, and the correlation coefficient r_p of the prediction set was 0.914 and RMSEP was 0.561 N mm^{-1}.

ACKNOWLEGMENT

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Oral Session | Postharvest/Food Technology and Process Engineering

[4-1600-A] Postharvest/Food Technology and Process Engineering (3)

Chair:Lotis Escobin Mopera(University of the Philippines Los Banos, Philippines), Natthawuddhi Donlao(Mae Fah Luang University, Thailand)

Wed. Sep 4, 2019 4:00 PM - 6:15 PM Hall A (Main Hall)

[4-1600-A-01] Electricity Production from Xylose in Microbial Fuel Cells Started with Three Different Inoculum Sources

*Yite Liu[1], Megumi Ueda[1], Tadashi Chosa[1], Seishu Tojo[1] (1. Tokyo University of Agriculture and Technology (Japan))

4:00 PM - 4:15 PM

[4-1600-A-02] Biodegradable Food Packaging from Cavendish Banana (*Musa acuminata*) Peduncle Fiber

Kittaporn Ngiwngam[1], Nor Jihan Jantan[2], *Wirongrong Tongdeesoontorn[1,3] (1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai 57100 (Thailand), 2. School of Industrial Technology, Universiti Teknologi MARA, Shah Alam, Selangor 42300 (Malaysia), 3. Research Group of Innovative Food Packaging and Biomaterials, Mae Fah Luang University, Chiang Rai, 57100 (Thailand))

4:15 PM - 4:30 PM

[4-1600-A-03] Assessment of the Physical Characteristics of Maize (Zea mays) stored in different Positions within the Metallic Silos

*BABATOPE ALBERT ALABADAN[1], CALLISTUS A. OKOLO[2] (1. Federal University, Oye Ekiti (Ikole Ekiti Campus)(Nigeria), 2. Federal University of Technology, Minna(Nigeria))

4:30 PM - 4:45 PM

[4-1600-A-04] Rice Analogue: Technology for Rice Enrichment and Food Diversification

*Lerjun Monilla Penaflor[1] (1. Food Engineering Division, Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Banos (Philippines))

4:45 PM - 5:00 PM

[4-1600-A-05] Optimization of Process Conditions for *Batuan* [*Garcinia binucao* (Blanco) Choisy] Fruit Powder Production

*Al Kaxier Guzman Ancheta[1], Erlinda I. Dizon[2] (1. University of the Philippines Los Banos(Philippines), 2. University of the Philippines Los Banos (Philippines))

5:00 PM - 5:15 PM

[4-1600-A-06] Effect of Processing Conditions on Bioactive Compounds and Antioxidant Activities of Tea Infusion

*Wei Qin[1], Sunantha Ketnawa[1], Florencio, Jr. Collado Reginio[1,2], Ryutaro Yamada[3], Takuya Araki[3], Yukiharu Ogawa[1] (1. Graduate School of Horticulture, Chiba University.(Japan), 2. Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baños(Philippines), 3. Institute of Fruit Tree and Tea Science, NARO(Japan))

5:15 PM - 5:30 PM

[4-1600-A-07] *In Vitro* Release Characteristics of Sugars and Hydrolysis of Starch During Simulated Digestion of Saba banana at Different Maturity

Stages

*Florencio, Jr. Collado Reginio[1,2], Wei Qin[1], Yukiharu Ogawa[1] （1. Graduate School of Horticulture, Chiba University(Japan), 2. Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Bañ os(Philippines)）

5:30 PM - 5:45 PM

[4-1600-A-08] *In Vitro* Examination of Starch Digestibility and Antioxidant Activities of Amaranth Grains

*Xiaoyan Xiong[1], Florencio Jr. Collado Reginio[1,2], Sukanya Thuengtung[1], Sunantha Ketnawa[1], Yukiharu Ogawa[1] （1. Graduate School of Horticulture, Chiba University(Japan), 2. Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baños(Philippines)）

5:45 PM - 6:00 PM

[4-1600-A-09] Effects of Cell Structure Changes of Citrus Peel on the Digestibility of Intracellular Antioxidants during *in vitro* Digestion

*Yidi Cai[1], Yukiharu Ogawa[1] （1. Graduate School of Horticulture, Chiba University(Japan)）

6:00 PM - 6:15 PM

Oral Session | Postharvest/Food Technology and Process Engineering
[4-1600-A] Postharvest/Food Technology and Process Engineering (3)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Hall A (Main Hall)

[4-1600-A-01] Electricity Production from Xylose in Microbial Fuel Cells Started with Three Different Inoculum Sources

*Yite Liu[1], Megumi Ueda[1], Tadashi Chosa[1], Seishu Tojo[1] （1. Tokyo University of Agriculture and Technology (Japan)）

Keywords: Microbial fuel cell, Xylose, Power generation, Biomass energy

Lignocellulosic biomass from agricultural residues is considered as a promising feedstock for the productions of bioethanol. However, the conversion of bioethanol fermentation from lignocellulosic biomass is limited since its low efficiency of utilization of xylose. Microbial Fuel Cells (MFCs), the bioelectrochemical systems that use microorganisms as biocatalysts to oxidize organic and inorganic matters and recover electrons, shows the possibility to degrade xylose and generate electricity directly. This study aimed to investigate how the substrate was degraded and characteristics of electricity generation were influenced by comparing 3 different inoculum sources in the MFCs using xylose and acetate (reference) as sole carbon source. Six membrane-less MFCs with a single chamber and air-cathode in total volume of 26mL were inoculated with 3 inoculum sources, methane fermentation broth, cow dung compost and anaerobic sludge from a sewage treatment facility, respectively with two repetitions. The voltage across an external electric resistor in the circuit of the MFC was measured with a data logger at 5 minutes interval. Concentrations of xylose and volatile fatty acids were analyzed by HPLC after the depletion of carbon source. Polarization curves were made by varying the external resistance from 10 ohms to 1000 ohms. Coulombic Efficiency (CE) was calculated according to reduced carbon source and produced total coulombs by integrating the current over time. Results showed that all the three inoculums contained electrogenic bacteria, and the MFCs produced steady electricity from both acetate and xylose, whereas the characteristics of voltage output, substrate degradation and CE are different.

Electricity Production from Xylose in Microbial Fuel Cells Started with Three Different Inoculum Sources

Yite Liu[1], Megumi Ueda[1], Tadashi Chosa[1], Seishu Tojo[1*]
[1]Tokyo University of Agriculture and Technology, Japan

tojo@cc.tuat.ac.jp

ABSTRACT

Lignocellulosic biomass from agricultural residues is considered as a promising feedstock for the productions of bioethanol. However, the conversion of bioethanol fermentation from lignocellulosic biomass is limited since its low efficiency of utilization of xylose. Microbial Fuel Cells (MFCs), the bioelectrochemical systems that use microorganisms as biocatalysts to oxidize organic and inorganic matters and recover electrons, shows the possibility to degrade xylose and generate electricity directly. This study aimed to investigate how the substrate was degraded and characteristics of electricity generation were influenced by comparing 3 different inoculum sources in the MFCs using xylose and acetate (reference) as sole carbon source. Six membrane-less MFCs with a single chamber and air-cathode in total volume of 26mL were inoculated with 3 inoculum sources, methane fermentation broth, cow dung compost and anaerobic sludge from a sewage treatment facility, respectively with two repetitions. The voltage across an external electric resistor in the circuit of the MFC was measured with a data logger at 5 minutes interval. Concentrations of xylose and volatile fatty acids were analyzed by HPLC after the depletion of carbon source. Polarization curves were made by varying the external resistance from 10 ohms to 1000 ohms. Coulombic Efficiency (CE) was calculated according to reduced carbon source and produced total coulombs by integrating the current over time. Results showed that all the three inoculums contained electrogenic bacteria, and the MFCs produced steady electricity from both acetate and xylose, whereas the characteristics of voltage output, substrate degradation and CE are different.

Keywords: Microbial fuel cell Xylose Power generation Biomass energy

1. INTRODUCTION

With the depletion of global fossil fuels and environmental pollution, renewable energy has received widespread attention increasingly (Mäkinen et al., 2013). Since its abundance, low pollution and great benefit for human society, ethanol production from lignocellulosic biomass became one of the most promising alternatives to replace traditional fossil energy.

However, the economical bio-ethanol production would be achieved only if both hexose and pentose sugars from lignocellulosic biomass are converted to ethanol efficiently. Although significant improvements such as recombination have been made in the microorganisms for improving the efficiency of converting pentose sugars into ethanol, the bioconversion of pentoses to ethanol is still one of the major bottlenecks for practical application (Kuhad et al., 2011).

Xylose, the most representative pentose, also the second most abundant carbohydrate after glucose from lignocellulose hydrolysate (Rubin, 2011), has been investigated in few studies. Those studies indicated stirring, initial concentration, fed-batch or continuous-flow, temperature, and use of electron mediator, have influence on the power generation of the xylose-fed MFCs (Huang et al., 2008a; Huang et al., 2008b; Dessì et al., 2018; Thygesen et al., 2009). However, the influences from different inoculums have not been published before.

In this study, to find better inoculums for electricity generation from xylose, characteristics of substrate degradation and electricity generation were investigated in the xylose-fed MFCs starting with three different inoculums.

2. MATERIALS AND METHODS

2.1 Inoculums

Three different inoculums describe below were inoculated to the duplicate MFCs respectively. (i) Methane fermentation broch from the biomass plant, Ogawa-machi, Saitama, Japan. (ii) Cow dung

compost from FS Center, TUAT, Fuchu-shi, Tokyo, diluted with 3 times volume of distilled water, and then filtered with a net before inoculating. (iii) Anaerobic sludge from North Tama Water Treatment Center, Fuchu-shi, Japan, without pretreatment. All the inoculums were stored in a refrigerator at 4°C.

2.2 MFC construction and operation

Six membrane-less MFCs with a single chamber and air-cathode in total volume of 26 mL were used in this study. Carbon cloth (TORAYCA cloth CO6343, TORAY, Japan) was used as anode after treated in a muffle furnace at 450 °C for 30min. The air-cathode was made of carbon cloth (EC-CC1-060T, ElectroChem, Inc, America) with a platinum (0.5 mg/cm^2) catalyst layer on the water side, and four layers of polytetrafluoroethylene (PTFE) diffusion were coated on the air side to prevent water (Cheng et al., 2006). Anode and cathode (reaction surface area of 9.62 cm$^{2)}$ were placed on the front and rear sides of the chamber, connecting with two twisted titanium wires served as current collectors. In order to change medium, 2 holes were drilled on the left and right side of the MFC respectively.

The medium containing was as follows (per liter): 0.31 g NH_4Cl, 0.13 g KCl, 2.54 g NaH_2PO4, 10.32 g $NaH_2PO_4 \cdot 12H_20$, 5 ml MEM Vitamin, 12.5 ml mineral solution. The mineral solution containing was as follows (per litter): 3 g $MgSO_4 \cdot 7H_2O$, 0.5 g $MnSO_4 \cdot H_2O$, 1 g NaCl, 0.1 g $FeSO_4 \cdot 7H_2O$, 0.1 g $CoCl_2 \cdot 6H2O$, 0.1 g $CaCl_2$, 0.1 g $ZnSO_4 \cdot 7H_2O$, 0.01 g $CuSO4 \cdot 5H_2O$, 0.01 g H_3BO_3, 0.01 g $Na_2MoO_4 \cdot 2H_2O$ and 0.02 g $NiCl_2 \cdot 6H_2O$. Sodium acetate (1g/L, control) or xylose (1g/L) as carbon source.

The inoculum sources were mixed with sodium acetate medium (v/v=1:1) for the initiation of the MFCs and replaced 2 or 3 times to form the bio-film on anode surface. After obtaining stable electricity generation, the mixed medium was changed to sodium acetate medium then xylose medium. Medium was fully discarded and refilled each time when the voltage decreased to under 0.05 V. Before polarization curve and measurement of organic acid or xylose, mediums were changed at least 3 times. All MFCs were operated at 30 °C in an incubator under fed batch conditions.

2.3 Analytical methods

MFCs connected with an external electric resistance (1000 ohms) in parallel, and the voltage across the resistance was recorded every 5 minutes by a data logger (GL240, GRAPHTEC, Japan).

Coulombic efficiency (CE), which defined as the fractional recovery of electrons from the substrate, was calculated by the following equation (Oh et al., 2004).

$$CE = \frac{M_s \int_0^t Idt}{F b_{es} V_{An} \Delta c} \qquad (1)$$

where, M_s is the molecular weight of substrate, t is the run time from medium replacement to the depletion of substrate, I is the current calculated as $I = V/R$, F is Faraday's constant, b_{es} is the number of electrons exchanged per mole of substrate (Accounting 20 mol electrons exchanged per mol of xylose and 8 mol for acetate), V_{An} is the volume of the MFC, Δc is the replacing time in the substrate over time t.

For calculating the maximum power density, polarization curves were made by varying the external resistance (Open circuit, 1000, 510, 240, 100, 51, 10 ohms). Power was calculated as $P = V^2/R$ and power density was calculated by the area of the anode.

After at least 3 times of replacing medium, the medium of MFCs were sampled at the end of batch cycle (Voltage < 0.05V). Time of depletion of one cycle was calculated from medium replacing until the voltage decrease under 0.05V.

Organic acids decomposed from xylose (Huang et al., 2008a) were performed on lactic acid, formic acid, acetic acid, propionic acid by HPLC (Shimadzu, UFLC Prominence) with column: Shim-pack SCR-102H (Shimadzu GLC) and detector: CDD-6A (Shimadzu). Xylose was measured by HPLC (Shimadzu, UFLC Prominence) with column: Shim-pack ISA-07/S2504 (Shimadzu GLC) and detector: RF-10AXL. All the operations were measured according to the instrument manufacturer's protocol.

3. RESULTS AND DISCUSSION

3.1 Electricity generation characteristics

After several cycles (3 cycles fed by sodium acetate or 6 cycles fed by xylose), the duplicate MFCs showed similar trends of electricity generation (maximum voltage, maximum power density,

corresponding resistance of maximum power density, CE and time of depletion) for methane fermentation broth-inoculated MFCs (Methane1 and Methane2) and sludge-inoculated MFCs (Sludge1 and Sludge2), while cow dung compost-inoculated MFCs (Compost1 and Compost2) were slightly different (Table 1).

Table 1. Electricity generation characteristics of MFCs fed by sodium acetate and xylose.

Substrate	Characteritics	Methane1	Methane2	Compost1	Compost2	Sludge1	Sludge2
Sodium Acetate (1g/L)	Maximum voltage (V)	0.540	0.552	0.528	0.574	0.571	0.571
	Maximum power density (mW/m^2)	718.93	675.86	493.33	648.61	745.86	710.35
	Corresponding resistance of maximum power density (ohms)	100	100	510	240	240	240
	CE (%)	25.96	23.46	15.54	17.53	16.08	17.69
	Time of depletion (h)	41.17	37.50	25.00	30.17	30.83	29.25
Xylose (1g/L)	Maximum voltage (V)	0.556	0.573	0.554	0.575	0.581	0.592
	Maximum power density (mW/m^2)	665.48	662.09	442.56	605.77	720.91	774.64
	Corresponding resistance of maximum power density (ohms)	240	240	510	240	240	100
	CE (%)	16.44	17.43	15.12	16.96	16.64	18.69
	Time of depletion (h)	40.67	39.83	34.17	40.42	42.75	43.92

3.2 Voltage

The voltage of the last cycle fed by sodium acetate and the sixth cycle fed by xylose were showed in Figure 1, and the initial six cycles fed by xylose (except for the cycle for measuring power density) was showed in Figure 2.

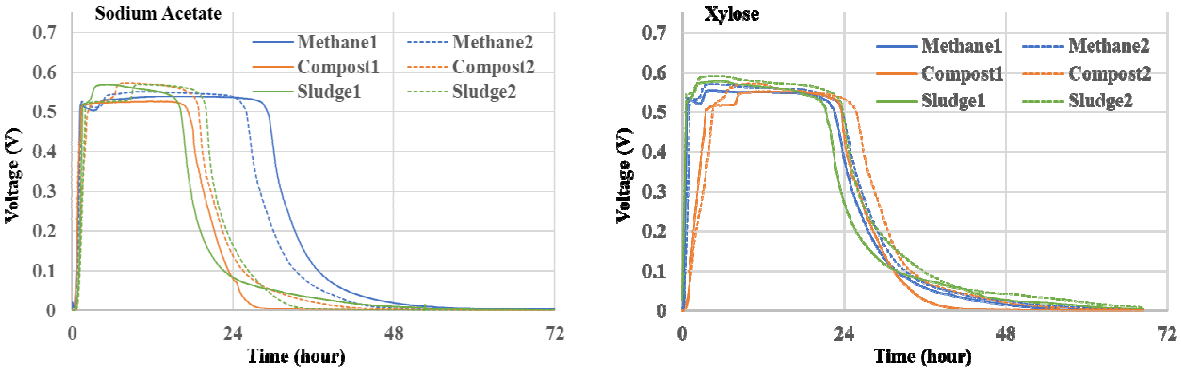

Figure 1. Voltage by time. Last cycle fed by sodium acetate and the 6th cycle fed by xylose.

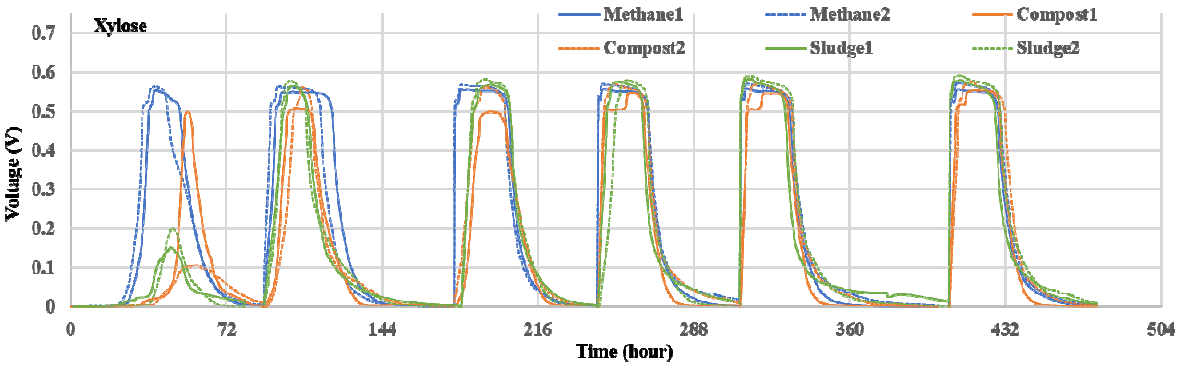

Figure 2. Voltage of the initial six cycles fed by xylose.

3.3 Adoption of xylose

As the increment number of cycles, voltage, time of depletion and CE became similar in all the MFCs fed by xylose (Figure 2 & Figure 3). Time of depletion was decreased, and CE was increased in the 6 cycles. Time of depletion ranged from 55.3 to 74.2 hours in the first cycle while it ranged from 34.9 to 43.8 hours in the sixth cycle. CE ranged from 3.03 % to 14.49 % in the first cycle while it ranged from 15.12 % to 18.69 % in the sixth cycle. Methane fermentation broth-inoculated MFCs showed shortest adaptation time, reached comparatively high CE and voltage almost at the first cycle with short lag time.

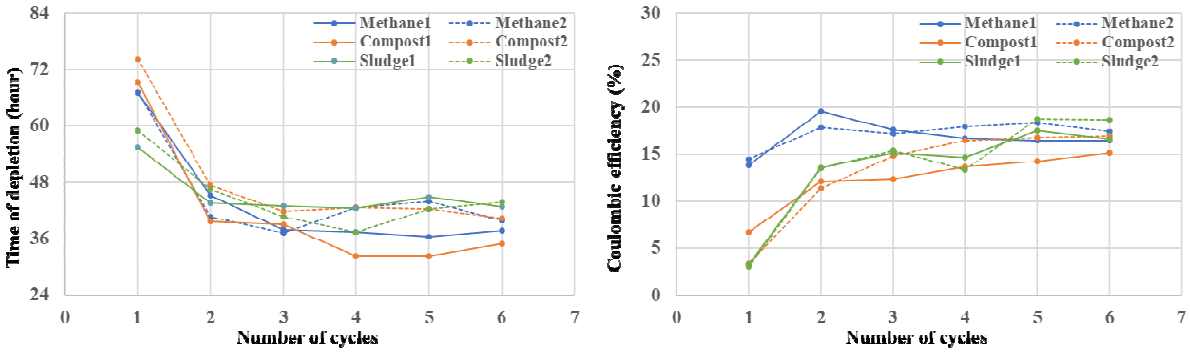

Figure 3. Time of depletion and coulombic efficiency changing by number of cycles.

3.4 Performance assessment of MFCs

According to the last cycle of sodium acetate and the sixth cycle of xylose, the performances of MFCs were as shown in Figure 4. Fed by xylose, sludge-inoculated MFCs had the highest of maximum voltage, maximum power density and CE although the longest time of depletion. Comparing with the methane fermentation broth-inoculated MFCs and sludge-inoculated MFCs respectively, the maximum voltage was 3.8 % and 3.8 % higher, the maximum power density was 11.2 % and 29.9 % higher, the CE was 4.1 % and 9.2 % higher, and the time of depletion was 7.1 % and 13.9 % longer. The performance of methane fermentation broth-inoculated MFCs were slightly lower than sludge-inoculated MFCs, however they had much higher CE when fed by sodium acetate. Cow dung compost-inoculated MFCs had the lowest maximum power density and CE, and it is possibly due to the different performance of the duplicate MFCs.

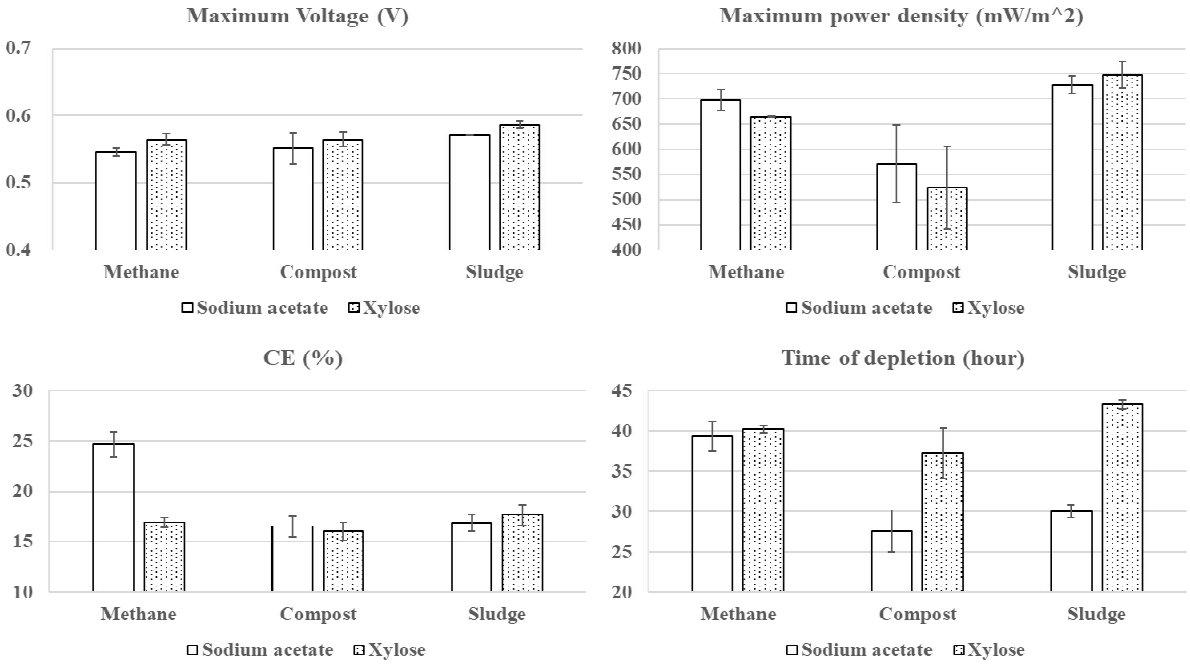

Figure 4. Performances of MFCs inoculated by different inoculum sources.

3.5 Substrate degradation

After at least 3 cycles of medium replacement, xylose and organic acid (lactic acid, formic acid, acetic acid, and propionic acid) were not detected by HPLC at the end of cycle (Voltage below 0.05V).

4. CONCLUSION

In this study, the characteristics of electricity generation was investigated in xylose-fed MFCs starting with three different types of inoculum sources, methane fermentation broth, cow dung compost and anaerobic sludge. Sludge-inoculated MFCs had the highest performance of electricity generation while methane fermentation broth-inoculated MFCs had the shortest adaptation time for xylose.

ACKNOWLEDGMENT

The authors thank for the support of JSPS research grant (No.16H05003) and the help from all students in Postharvest Engineering and Renewable Energy Laboratory, TUAT, Japan.

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4:15 PM - 4:30 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Hall A)

[4-1600-A-02] Biodegradable Food Packaging from Cavendish Banana (*Musa acuminata*) Peduncle Fiber

Kittaporn Ngiwngam[1], Nor Jihan Jantan[2], *Wirongrong Tongdeesoontorn[1,3] (1. School of Agro-Industry, Mae Fah Luang University, Chiang Rai 57100 (Thailand), 2. School of Industrial Technology, Universiti Teknologi MARA, Shah Alam, Selangor 42300 (Malaysia), 3. Research Group of Innovative Food Packaging and Biomaterials, Mae Fah Luang University, Chiang Rai, 57100 (Thailand))

Keywords: Cavendish banana, Banana peduncle, Fiber, Biodegradable food packaging, Waste utilization

This study deals with the determination of chemical composition and the study of the pulping potentialities of banana peduncle waste in Chiang Rai, Thailand to produce biodegradable food packaging. Before the pulping process, chemical composition of banana fiber (BF) was identified. The result showed that holocellulose content in banana peduncle was 54.6±4.42 % (w/w) dried sample then lignin content was 14.42±0.39% dried sample. The banana fiber consisted of alpha-, beta-, and gamma-cellulose contents 59.96±0.03%, 2.89±1.05%, 37.35±1.3% (w/w) of holocellulose, respectively. After that, the molded pulp tray from banana peduncle fiber was formed by using the hydraulic hot-pressing machine at 140 ° C, 250 psi for 7 minutes. Dried fiber around 15 g was used for the tray forming and the properties of the tray were determined. For color measurement, lightness (L*) of pulps were decreased from 46.47 to 38.18 by increasing NaOH concentration. Grammage of molded pulp trays from 10, 15, and 20% NaOH were 632.40± 25.37, 705.11±30.58, and 689.13±79.86 g/m², respectively. Tensile index and compression index of molded pulp tray at 10% NaOH showed the highest value as 22.12±1.23 MPa.m²/g and 25.03±1.04 MPa.m² /g. The tray at 20% NaOH gave the highest value of thickness swelling at 37.14±2.67%. The results indicated that the BF molded pulp tray from pulping process with 10% NaOH has good properties as high tensile index, compression index, MOR, and water wetting time which can be used as biodegradable food packaging.

Oral Session | Postharvest/Food Technology and Process Engineering
[4-1600-A] Postharvest/Food Technology and Process Engineering (3)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Hall A (Main Hall)

[4-1600-A-03] Assessment of the Physical Characteristics of Maize (Zea mays) stored in different Positions within the Metallic Silos

*BABATOPE ALBERT ALABADAN[1], CALLISTUS A. OKOLO[2] （1. Federal University, Oye Ekiti (Ikole Ekiti Campus)(Nigeria), 2. Federal University of Technology, Minna(Nigeria)）
Keywords: Maize, Storage, Metallic silos, Physical, Characteristics

The assessment of the moisture content (MC), hectoliter weight (HW), insect damage (ID), broken grains (BG), mould infestation (MI), viability/germinability (VG) and foreign matters (FM) of maize in different positions in the metallic silos during eight months storage was presented in this study. Seven and two positions in the maize bulk were investigated in the 250 MT and 1 MT silos respectively. The initial values obtained were compared with the values obtained during storage using statistical packages. The levels of significance for the variables are MC, 10.0±0.57%; HW, 72.9±0.10%; ID, 0.29±0.03%; BG, 0.55±0.01%; MI, 0.00±0.02%; VG, 100±0.00% and FM, 0.80±0.60% in respect to positions of the grains in the bulk. Variables were all significant (<0.05) except MC, HW and FM irrespective of the size of the metallic silos. The mean deviations of the variables from the control decreased for MC, HW, BG, VG and FM while ID and MI increased with storage period. The physical characteristics of maize were not influenced by the size of silo. The 1MT silo silo performed better in VG while bigger silo efficiency depends on the position of the grains in the bulk.

ASSESSMENT OF THE PHYSICAL CHARACTERISTICS OF MAIZE *(Zea mays)* STORED IN DIFFERENT POSITIONS WITHIN THE METALLIC SILOS

[1*]Babatope A. ALABADAN and Callistus A. OKOLO[2]

[1*]Department of Agricultural and Bioresources Engineering,
Federal University, Oye-Ekiti. Nigeria
babatope.alabadan@fuoye.edu.ng
*Corresponding author

[2] Department of Agricultural and Bioresources Engineering,
Federal University of Technology, Minna. Nigeria
budget.04united@yahoo.com

ABSTRACT

The assessment of the moisture content (MC), hectolitre weight (HW), insect damage (ID), broken grains (BG), mould infestation (MI), viability/germinability (VG) and foreign matters (FM) of maize in different positions of the metallic silos during eight months storage was presented in this study. Seven and two positions in the maize bulk were investigated in the 2500MT and 1MT silos respectively. The initial values obtained were compared with the values obtained during storage using statistical packages. The levels of significance for the variables are MC 10.0±0.57%, HW 72.9±0.10%, ID 0.29±0.03%, BG 0.55±0.01%, MI 0.00±0.02%, VG 100±0.00% and FM 0.80±0.60% in respect to positions of the grains in the bulk. Variables were all significant ($p<0.05$) except MC, HW and FM irrespective of the size of the metallic silos. The mean deviations of the variables from the control decreased for MC, HW, BG, VG and FM while ID and MI increased with storage period. The physical characteristics of maize were not influenced by the size of silo. The 1 MT silo performed better in VG while bigger silo efficiency depends on the position of the grains in the bulk.

Keywords: Maize, storage, metallic silos, physical characteristics

4:45 PM - 5:00 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Hall A)

[4-1600-A-04] Rice Analogue: Technology for Rice Enrichment and Food Diversification

*Lerjun Monilla Penaflor[1] (1. Food Engineering Division, Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Banos (Philippines))
Keywords: rice analogue, rice enrichment, food diversification, cereal grains, tubers crops

An optimization process for making rice-like kernels or rice analogue through cooking the fusion of different cereal grains and tuber crops mixed with water to produce a partially gelatinized mixture then extruded forming a rice shaped kernel and finally dried and cooled. The objective of the study is to develop a technology for reconstituting broken milled rice and explore the potentials of other cereal grains and tuber crops to enhance the nutritional composition and physico-chemical properties of the rice analogue specifically investigate its possibilities as a medium for rice enrichment and food diversification.The fusion of different cereal grains and tubers crops is suitable approach for enhancing the nutritional composition and physicochemical properties of the rice analogue. The products meets the nutritional criteria and could be developed as a medium for rice enrichment, as well as a food diversification for billion people. It deals an innovative technique of utilizing locally available grains and carbohydrate sources into a new staple food, but appropriate processing technology and comprehensive research is essential for developing rice analogue with specific functional properties, such as low glycemic index, high protein and fiber content. An appropriate medium should be widely adopted, but not require changes to daily healthy metabolism at the same time makeable from a wide range of sources. Rice analogue has the potential to provide for an observable gap in current fortification systems. The establishment of a new model offers a novel way to encourage people to food diversification and promote rice analogue.

Oral Session | Postharvest/Food Technology and Process Engineering
[4-1600-A] Postharvest/Food Technology and Process Engineering (3)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Hall A (Main Hall)

[4-1600-A-05] Optimization of Process Conditions for *Batuan* [*Garcinia binucao* (Blanco) Choisy] Fruit Powder Production

*Al Kaxier Guzman Ancheta[1], Erlinda I. Dizon[2] (1. University of the Philippines Los Banos(Philippines), 2. University of the Philippines Los Banos (Philippines))

Keywords: batuan fruit powder, response surface methodology

The study determined the optimum process conditions to produce *batuan* fruit powder using Response Surface Methodology (RSM). The factors considered were sodium metabisulfite (SMS) concentration and drying temperature. Results revealed the significant responses based on physico-chemical (titratable acidity, total soluble solids, whiteness index) and functional (antioxidant activity, total phenolics, water absorption index, water solubility index) characteristics of the powder. However, the responses that were not significant in the model were also identified based on physico-chemical (pH, bulk density, fineness modulus) and functional (none) characteristics. Hence, the optimum drying temperature and SMS concentration were found to be 50.0˚C and 106 ppm, respectively. The optimum conditions were used to produce the powder to verify the predicted physico-chemical and functional properties.

Optimization of Process Conditions for *Batuan* [*Garcinia binucao* (Blanco) Choisy] Fruit Powder Production

Al Kaixer G. Ancheta[1,*] and Erlinda I. Dizon[2]

[1]Department of Engineering Science, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños, Laguna, Philippines
[2]Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baños, Laguna, Philippines

[*]Corresponding author; email: agancheta2@up.edu.ph

ABSTRACT

The study determined the optimum process conditions to produce *batuan* fruit powder using Response Surface Methodology (RSM). The factors considered were sodium metabisulfite (SMS) concentration and drying temperature. Results revealed the significant responses based physicochemical (titratable acidity, total soluble solids, whiteness index) and functional (antioxidant activity, total phenolics, water absorption index, water solubility index) characteristics of the powder. However, the responses that were not significant in the model were also identified based on physicochemical (pH, bulk density, fineness modulus) and functional (none) characteristics. Hence, the optimum drying temperature and SMS concentration were found to be 50.0°C and 106 ppm, respectively. The optimum conditions were used to produce the powder to verify the predicted physicochemical and functional properties.

Keywords: *Batuan* fruit, *Batuan* fruit powder, Response surface methodology, Sodium metabisulfite, Drying

1. INTRODUCTION

Tamarind is considered as the most popular souring agent in Philippines and is used as a base in soup dishes such as *sinigang*. However, the supply of locally available tamarind may not be able to meet the huge consumer demand due to the increase in population. Philippines is continuously importing tamarind to meet the domestic needs (Valencia, 2013a; Reyes, 2000; Mojica, 2008). Thus, an alternative souring agent should be considered.

Nowadays, the potential of conversion of underutilized crops into high value products are looked upon by researchers (Ebert, 2014; Valencia, 2013b; Florido and Cortiguerra, 2003). *Batuan* fruit is one of the indigenous crops that is popular in the southern part of Philippines as souring agent instead of tamarind. A study by Quevedo *et al.* (2013) revealed the potential of using *batuan* fruit not only as a souring agent but also one that is safe for consumption and rich in nutrients. Thus, *batuan* is indeed a promising alternative souring agent.

Even though *batuan* fruit is abundant, it is seasonal so that it is available only from April to June in Philippines. Thus, preservation of this fruit is necessary to make it available all year round and to extend its shelf-life, one of which is to turn it into powder.

There are already numerous researches about production of powders from fruits such as mango powder (Jaya and Das, 2005), date powder granules (Sablani *et al*., 2008), gac fruit aril powder by spray drying (Kha *et al*., 2010), tamarind powder by drum drying using maltodextrin and arabic gum as adjuncts (Jittanit *et al*., 2011), then comparison of qualities of tamarind powder using tray and drum dryers (Khuenpet *et al*., 2012), fiber-rich powder from dragon fruit or *pitaya* peel (Senghkhamparn *et al*., 2013), and mango kernel flour using cabinet dryer (Bawar, 2013), and spray-dried soursop powder (Chang *et al*., 2018; Chang *et al*., 2019) among others. There are also published studies about *batuan* fruits' physicochemical properties, nutritional and sensory qualities (Quevedo *et al*., 2013), organic acid profile (Quevedo *et al*., 2013), and

hydroxycitric acid content that is affected during processing (Bainto *et al*., 2018). However, there is no published research yet that is specific to *batuan* fruit powder.

The production of the powder included drying, grinding, and other interventions such as inactivation of enzymes and addition of preservatives to ensure a high quality product. Drying using hot air was done to remove most of the moisture and to produce a powder with good flowability. Sodium metabisulfite (SMS) was added as anti-browning agent. Hence, this study aimed to establish the procedure to produce powder, a high-value product, from the pulp of the *batuan* fruit. Also, the optimum SMS concentration and drying temperature were determined based on the physicochemical and functional characteristics for *batuan* fruit powder processing.

2. MATERIALS AND METHODS

2.1. Time and Place of the Study

The study was conducted from September to December 2014 at the Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baños, Laguna, Philippines.

2.2. Source of *Batuan* Fruits

Batuan fruits were obtained from a local market in Bacolod City, Philippines and then shipped to University of the Philippines Los Baños. The fruits used in the experiment had characteristic green color, hard covering, and medium to large size (about 3.7–5.5 cm in diameter) only (Fig. 1). The sizes that were used in the study were the 3 largest diameters which are medium to large (Fig. 1b).

(a) (b)

Figure 1. Fresh *batuan* fruits in (a) bulk and (b) relative sizes used in the study.

2.3. Preparation of Frozen *Batuan* Fruits

As soon as the fresh and immature *batuan* fruits were received, the fruits were washed initially with tap water to minimize microbial load and other adhering contaminants, then, the whole fruits were disinfected by soaking in 10 ppm hypochlorous acid (HOCl) solution for 20 seconds to further decrease or eliminate its initial microbial load. The fruits were washed again in running potable water to remove excess chlorine in the fruits. Afterwards, the fruits were packed in PE bags (about 10 kg per bag), and stored in a chest freezer at -20°C to stop biochemical and microbial degradation of the fruits. Before processing into powder, the frozen fruits were thawed in running water for about 5 min and drained well.

2.4. Pre-drying Treatments

The whole fruits were cooked using a steamer for 20 min or until the color of the peel has completely changed from green to yellowish brown (Fig. 2). Steaming was necessary to inactivate the enzymes and to soften the pulp for easier removal by the pulping machine. After steaming, the cooked fruits were immediately cooled with running water to stop further heating. Then, the steamed fruits were fed through a pulping machine to separate the seeds and recover the pulp (Fig. 3 and Fig. 4).

Figure 2. *Batuan* fruits during steaming.

Figure 3. Pulping of steamed *batuan* fruits.

Figure 4. *Batuan* pulp recovered after pulping.

The recovered pulp (Fig. 4) was separated into 3 lots where each lot was treated with a predetermined amount of 10% sodium metabisulfite (SMS). SMS was added to the pulp so that the pulp would contain 0 (control), 125 ppm, and 250 ppm concentration.

2.5. Convective Drying of *Batuan* Fruit Pulp

A cabinet dryer, available in the pilot plant of Institute of Food Science and Technology, CAFS, UPLB, was used to dry the pretreated samples. The pulp (Fig. 5a) was laid on stainless steel trays layered with polyethylene to prevent the pulp from sticking onto the trays after drying. The thickness of the pulp on the trays was set at 3 mm maximum to allow faster drying. Three different drying temperatures (50°C, 60°C, and 70°C) were employed in the study. The drying of the pulp was continued until the sample reached a moisture content of about 10.75% such that the product became brittle in texture. The dried pulp (Fig. 5c) was like thin, brittle, brown flakes (ready for grinding) that were scraped using a spatula.

(a) (b) (c)

Figure 5. Drying of *batuan* pulp showing (a) spreading on trays, (b) loading of trays inside the convective dryer, and (c) dried pulp.

2.6. Grinding and Sieving

A grinder (Koii® Platinum Edition, Koii Philippines) was used to grind the dried pulp. The produced powder was sieved using 60 mesh USA sieve to obtain a finer powder (Fig. 6b). Then the produced powder samples were immediately packed in glass bottles at room temperature for storage.

(a) (b)

Figure 6. Sieving of *batuan* powder using 60 mesh USA sieve showing (a) reject oversize and (b) product undersize.

2.7. Optimization of *Batuan* Fruit Powder Production

The combination of the varying SMS concentrations (0, 125 ppm, and 250 ppm) and drying temperatures (50°C, 60°C, and 70°C) resulted in 9 different treatments under study.

Based on the results of physicochemical and functional analyses, an optimum condition, which is the most acceptable, was determined using Design Expert® computer software. Statistical analysis was also done to determine whether or not the differences in the attributes are significant.

After determining the optimum condition based on analysis of physicochemical and functional properties, the optimized sample was produced following the computed optimum conditions, and analyzed of its physicochemical and functional properties to verify the correctness of the optimum condition determined using the software.

2.8. Physicochemical Analysis

The *batuan* fruit powder samples were subjected to physicochemical analysis in terms of bulk density (BD), fineness modulus (FM), pH, TA, TSS, and WI.

2.8.1. Bulk density (BD). The powder sample was filled into a pre-weighed 50-mL graduated cylinder up to the 50-mL mark. No tapping or compression of the powder was done to avoid variation in the results. The values of BD were expressed in terms of g/mL.

$$\text{Bulk Density} = \frac{\text{mass of (sample + cylinder)} - \text{mass of cylinder}}{\text{volume of sample}}$$

2.8.2. pH. The pH of the *batuan* fruit powder was determined by using a pH pen (Eutech® Instruments pH 2700, Eutech Instruments Pte. Ltd., Singapore) in a 1:9 by weight (dilution factor of 10) mixture of *batuan* powder and distilled water.

2.8.3. Titratable acidity (TA). The *batuan* fruit powder was dissolved in freshly boiled and cooled distilled water at a ratio of 1:9 by mass (dilution factor of 10). The resulting solution was added with 2-3 drops of 1% phenolphthalein indicator and titrated using 0.1 M NaOH solution up to faint pink endpoint. Then the %TA (g citric acid/100 g sample) was calculated using the formula:

$$\%\text{TA} = \frac{\text{vol. titrant used (mL)} \times \text{N titrant} \times \text{eq. wt. acid } (= 64.04 \text{ for citric acid}) \times \text{DF}}{\text{vol. sample (mL)} \times 10}$$

2.8.4. Total soluble solids (TSS). The *batuan* fruit powder was dissolved in distilled water at a ratio of 1:9 by mass (dilution factor of 10). Using a refractometer (Cole-Parmer® Refractometer EW-81150-32, Cole-Parmer Instrument Company LLC, USA), the degree Brix (°Bx) of the solution was read.

2.8.5. Whiteness index (WI). The color of the sample was measured using a chromameter (X-Rite Capsure® RM200-PT01, X-Rite Inc., USA) as *L* (lightness), *a* (redness), and *b* (yellowness). The values of *L*, *a*, and *b* obtained were used to calculate the WI using the equation according to Sheen (1990), Tsai (1994), Hsu *et al.* (2003), and Bawar (2013):

$$\text{WI} = 100 - \sqrt{(100 - L)^2 + a^2 + b^2}$$

2.9. Functional Analysis

The powder samples were also subjected to functional analysis in terms of antioxidant activity, total phenolics, WAI, and WSI.

2.9.1. Antioxidant activity. The antioxidant activity of the *batuan* fruit powder was determined based on its ability to scavenge the stable DPPH. Fifty milligrams (50 mg) of the sample was placed in a test tube and then added with 5 mL of 80% methanol solution and mixed in a vortex mixer for 10 min. The mixture was then filtered in a test tube and kept refrigerated until use. A 1-mL aliquot was obtained and added with 4 mL distilled water. Freshly prepared 1 mL of 1 mM methanolic DPPH solution was added. The solutions were allowed to stand for 30 min. The absorbance of the solutions (sample and blank) was read at 517 nm (Bawar, 2013; Murthy *et al.,* 2002 as cited in Veigas *et al.,* 2007). The percentage scavenging activity of DPPH was computed using the equation:

$$\%\text{DPPH scavenging activity} = \left(1 - \frac{\text{absorbance test sample}}{\text{absorbance blank sample}}\right) \times 100$$

2.9.2. Total phenolics content. Folin-Ciocalteau Method was used to analyze total phenolics. The powder samples were diluted to 1000 µg/mL with 80% methanol solution and then filtered using Whatman® No. 1 filter paper to remove suspended solids (that may interfere during reading of absorbance using a spectrophotometer). Exactly 0.25 mL, each, of diluted samples and standard solutions (0, 40, 80, 100, 150 µg/mL gallic acid) was obtained and diluted with 3.5 mL distilled water. Then 0.5 mL of 50% Folin-Ciocalteau reagent was added followed by 1 mL of 20% Na_2CO_3 after 3 min. Then the samples were mixed and incubated in boiling water for 1 min to develop the blue color. Then absorbance of the samples was read at 685 nm. The total phenolics content of the samples was calculated based on linear regression analysis of the standard solutions.

2.9.3. Water absorption index (WAI) and water solubility index (WSI). WAI and WSI were determined in triplicates following the method by Anderson (1982 as cited in Narbutaite *et al.,* 2008). About 1 g of each sample was suspended in 6 mL of distilled water and stirred for 30 min at 30°C. Then, the mixture was centrifuged at 4000×*g* for 20 min. The supernatant liquid was poured into a dry 15-mL test tube and stored overnight at 110°C to evaporate the water. The WAI and WSI were computed using following equations:

$$\%\text{WSI} = \frac{\text{mass of dissolved solids in supernatant}}{\text{mass of sample}} \times 100$$

$$\text{WAI} = \frac{\text{mass of sediment}}{\text{mass of sample}}$$

2.10. Statistical Analysis

All analyses were done in triplicates. The determined values were expressed as mean ± standard deviation. Data were analyzed using Analysis of Variance (ANOVA) to determine if the samples

significantly differed from one another, followed by Tukey's Honest Significant Difference (HSD) Test to know which among the samples were significantly different.
The SMS concentration and drying temperature was optimized by response surface methodology (RSM) following the procedure of Design-Expert® (Version 9.0.3.1, Stat-Ease, Inc., MN, USA) computer software. ANOVA and HSD were done using Statistical Analysis System (SAS Version 9, SAS Institute Inc., USA) computer software.

2.11. Proximate Analysis

Proximate analysis was done to further identify the best (optimized) treatment for the *batuan* powder. The procedure based on AOAC (2000) was followed.

3. RESULTS AND DISCUSSION

The effects of varying SMS concentration (0, 125 ppm, 250 ppm) and drying temperature (50°C, 60°C, and 70°C) on the quality of *batuan* fruit powder (Fig. 7) were evaluated.

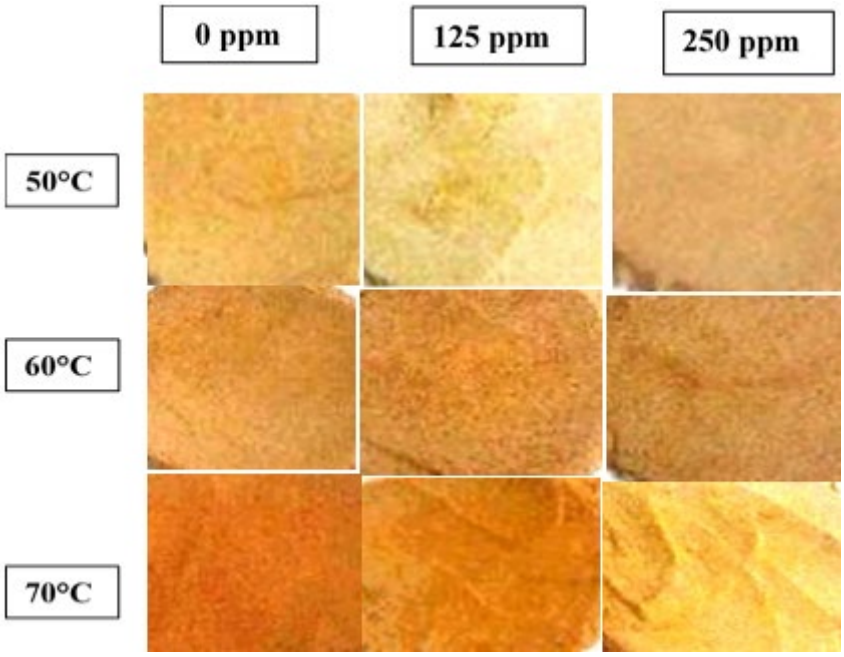

Figure 7. *Batuan* fruit powder produced at varying temperature and SMS concentration.

3.1. Effect of SMS Concentration and Drying Temperature on the Physicochemical Properties of *Batuan* Fruit Powder

3.1.1. Bulk density (BD). The bulk density accounts for the true volume occupied by the product and the volume of the voids or spaces between the particles. It is important because the volume of the packaging material necessary to accommodate a certain mass of product depends on it. Higher bulk density is favorable because at a certain mass of product, less volume is occupied and therefore the transport of the product from one place to another is easier.

The values of bulk density of *batuan* fruit powder were determined at varying temperature and SMS concentration (Table 1 and Fig. 8).

Table 1. Bulk density (g/mL) of *batuan* fruit powder at varying SMS concentration and drying temperature.

SMS CONCENTRATION (ppm)	DRYING TEMPERATURE (°C)		
	50	60	70
0	0.666 ± 0.025^{a}	0.620 ± 0.005^{a}	0.648 ± 0.007^{a}
125	0.654 ± 0.034^{a}	0.500 ± 0.002^{b}	0.637 ± 0.008^{a}
250	0.625 ± 0.030^{a}	0.416 ± 0.003^{c}	0.613 ± 0.004^{a}

Mean values of the same superscript for all treatments are not significantly different at $P \leq 0.05$, HSD.

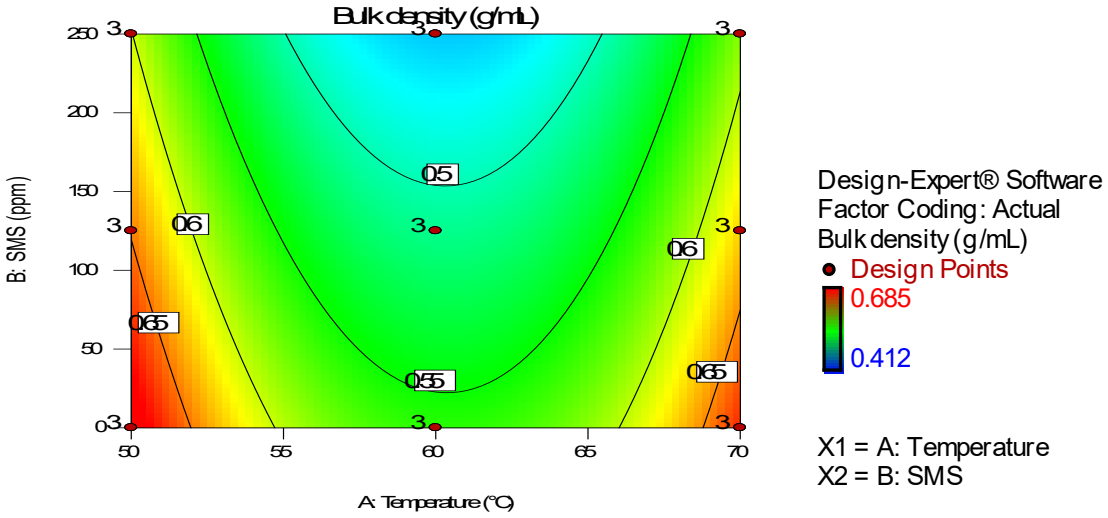

Figure 8. Contour plots of bulk density of *batuan* fruit powder versus drying temperature and SMS concentration.

The BD tends to decrease somewhere between 50°C and 70°C. There is also a positive correlation between the BD and the SMS content. Increasing the drying temperature may cause further shrinkage of the pulp during drying as the volatile substances escaped from the pulp so that the resulting powder would be more compact. The decrease in bulk density at greater temperature was observed by Kha *et al.* (2010) in spray drying of gac fruit aril powder. On the other hand, higher amount of SMS may result in better protection of the pulp from oxidation where the pulp would maintain its integrity or structure, but the effect of SMS on the BD became pronounced only at 60°C (Table 1). However, there is little or no research that could verify the role of SMS in changing the BD of a powder.

3.1.2. pH. The pH indicates the acidity of the product, however, it is not a direct measure of acidity. Nevertheless, the pH is important for the *batuan* fruit powder since it is the most important property for a souring agent. The pH may determine whether or not microorganisms would survive in the sample, or what group of microorganisms may grow. Table 2 and Figure 9 show the pH values of *batuan* fruit powder at varying SMS concentrations and temperatures.

Table 2. pH values of *batuan* fruit powder at varying SMS concentration and drying temperature.

SMS CONCENTRATION (ppm)	TEMPERATURE (°C)		
	50	60	70
0	3.40 ± 0.00[a]	3.33 ± 0.06[a]	3.40 ± 0.00[a]
125	3.40 ± 0.00[a]	3.37 ± 0.06[a]	3.40 ± 0.00[a]
250	3.40 ± 0.00[a]	3.37 ± 0.06[a]	3.37 ± 0.06[a]

Mean values of the same superscript for all treatments are not significantly different at $P \leq 0.05$, HSD.

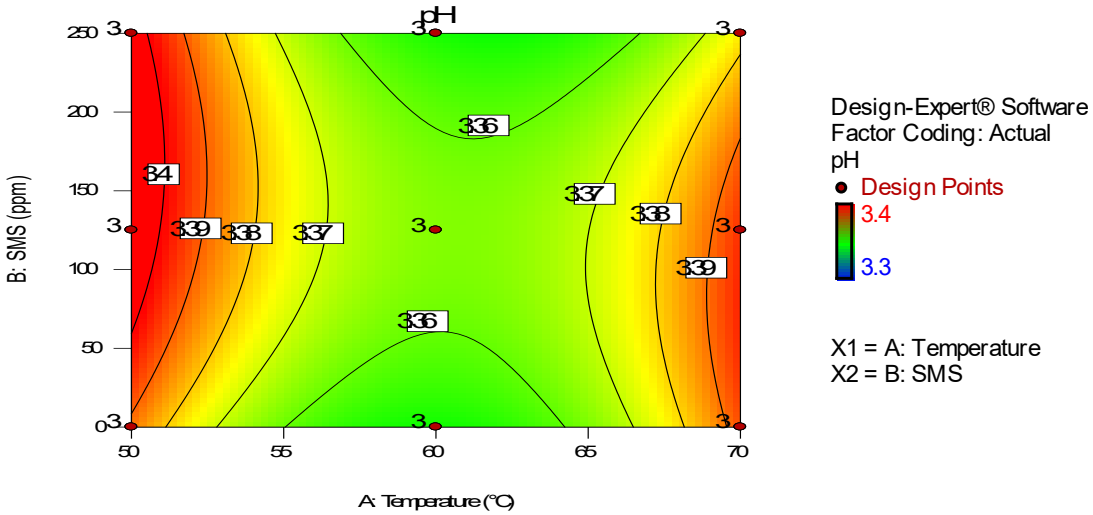

Figure 9. Contour plots of pH of *batuan* fruit powder versus drying temperature and SMS concentration.

The differences between pH values at varying SMS concentration and drying temperature are not significant based on Two-factor ANOVA at 5% level of significance. Nevertheless, slightly lower pH values were seen at 60°C.

3.1.3. Titratable acidity (TA). The TA is a better measure of the acidity than pH. Lower pH may measure the concentration of hydrogen ions (and consequently the amount of dissociated acids) but TA accounts all the acids present whether dissociated or not. High TA values were observed in Table 3 and Figure 10. The TA was expressed as percent citric acid because it is the predominant acid present in the *batuan* fruit (Quevedo *et al.* 2017).

Table 3. Titratable acidity (g citric acid/100 g sample) of *batuan* fruit powder at varying SMS concentration and drying temperature.

SMS CONCENTRATION (ppm)	TEMPERATURE (°C)		
	50	60	70
0	24.38 ± 1.29[a]	25.62 ± 1.43[a]	20.87 ± 0.36[b]
125	23.35 ± 0.72[a]	25.41 ± 1.24[a]	21.49 ± 0.95[b]
250	23.35 ± 1.79[a]	24.17 ± 1.24[a]	21.49 ± 0.95[b]

Mean values of the same superscript for all treatments are not significantly different at $P \leq 0.05$, HSD.

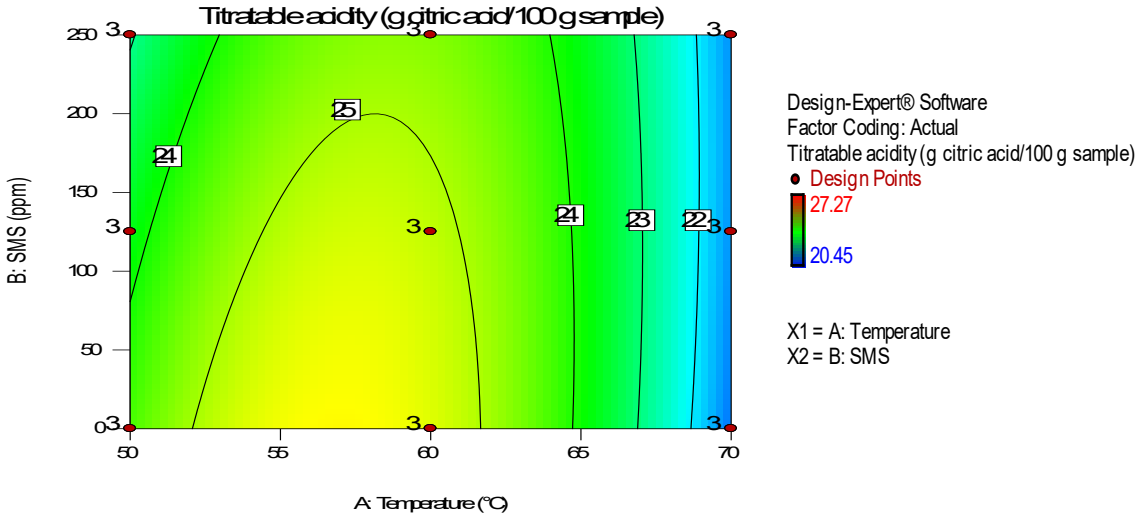

Figure 10. Contour plots of titratable acidity of *batuan* fruit powder versus drying temperature and SMS concentration.

The changes in TA may be primarily due to temperature only. Moreover, at 60°C, highest values of TA were seen. However, statistical analysis at 5% level of significance revealed that there are no significant differences between the TA values at 50°C and 60°C. Varying the SMS concentration did not have significant effect on the TA due to volatilization of SMS at high temperature during drying. Nonetheless, an optimum TA may be determined somewhere between 50°C and 70°C.

3.1.4. Total soluble solids (TSS). In Table 4 and Figure 11, the TSS values are tabulated and plotted, respectively.

Table 4. Total soluble solids (degree Brix) of *batuan* fruit powder at varying SMS concentration and drying temperature.

SMS CONCENTRATION (ppm)	DRYING TEMPERATURE (°C)		
	50	60	70
0	4.60 ± 0.00^{a}	4.67 ± 0.12^{a}	5.00 ± 0.00^{b}
125	4.60 ± 0.00^{a}	4.73 ± 0.12^{a}	5.00 ± 0.00^{b}
250	4.87 ± 0.12^{a}	4.53 ± 0.12^{a}	5.07 ± 0.12^{b}

Mean values of the same superscript for all treatments are not significantly different at $P \leq 0.05$, HSD.

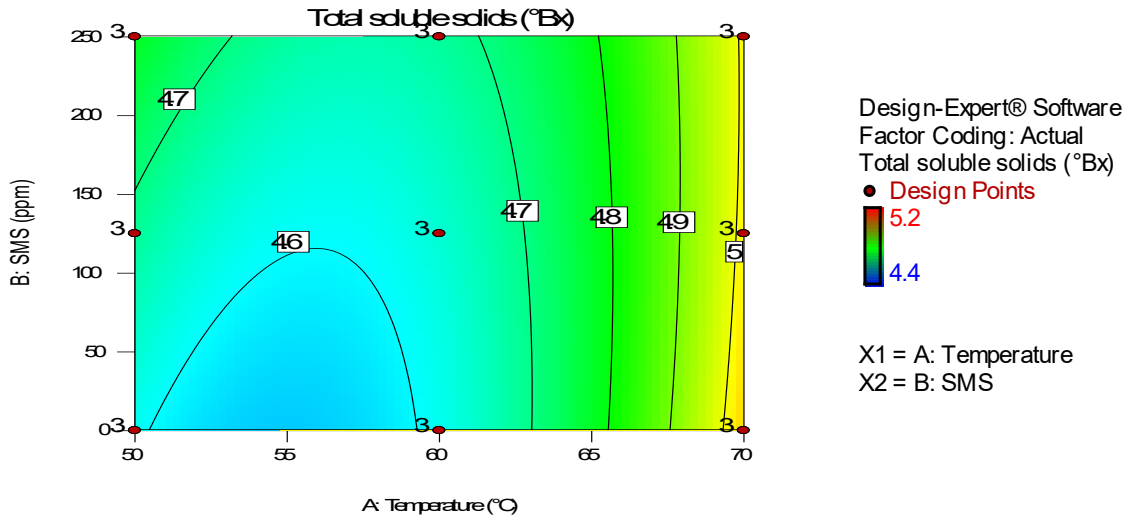

Figure 11. Contour plots of total soluble solids of *batuan* fruit powder versus drying temperature and SMS concentration.

It may be observed that the TSS generally increases with temperature, although the change in TSS was significant only at 70°C, possibly due to degradation of some components such as pectin and dietary fiber to form smaller units that are more water-soluble which were observed by Garau *et al.* (2007) in orange fruit, and de Roeck *et al.* (2008) in carrot tissue. On the other hand, the SMS did not play a role in varying the TSS of the powder. Based on Figure 11, the TSS exhibits a minimum value somewhere at 55°C.

3.1.5. Whiteness Index (WI). The values of WI range from 0 to 100 such that lighter samples have WI values approaching 100. This signifies that samples with higher WI have lighter color. The suggestion by Ajaykumar *et al.* (2012) to blanch and add sulfite to the samples was followed, and therefore, the decrease in browning (in terms of WI) of the samples was expected with increasing concentrations of SMS which is an anti-browning agent. The change in WI after varying the temperature and SMS content was shown (Table 5 and Fig. 12).

Table 5. Whiteness index values of *batuan* fruit powder at varying SMS concentration and drying temperature.

SMS CONCENTRATION (ppm)	DRYING TEMPERATURE (°C)		
	50	60	70
0	44.59 ± 2.03^{a}	44.61 ± 2.06^{a}	36.81 ± 4.55^{b}
125	46.94 ± 0.00^{a}	44.32 ± 1.02^{a}	41.34 ± 0.10^{b}
250	46.94 ± 0.00^{a}	43.85 ± 1.94^{a}	39.33 ± 3.58^{b}

Mean values of the same superscript for all treatments are not significantly different at $P \leq 0.05$, HSD.

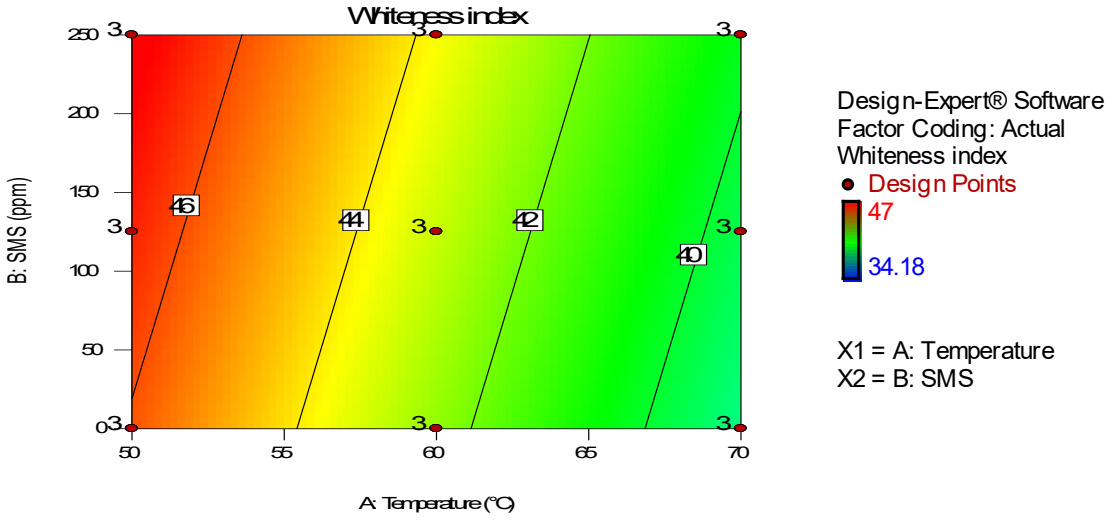

Figure 12. Contour plots of whiteness index of *batuan* fruit powder versus drying temperature and SMS concentration.

The general trend is that the WI decreased when the drying temperature increased while the WI increased slightly when SMS concentration became greater. However, based on statistical analysis at $P \leq 0.05$, even though the model is significant and the lack of fit is not significant, only the drying temperature is a significant factor that affects the WI. Nevertheless, the combined effects of temperature and SMS concentration may result in an optimum WI somewhere at the upper left corner of the region in Figure 12. The decrease in WI at increasing temperature may be due to increased rate of browning reactions at higher temperature. On the other hand, increasing the SMS content did not significantly affect the color even with the ability of SMS to inhibit browning reactions due to volatilization of SMS during drying.

3.2. Effect of SMS Concentration and Drying Temperature on the Functional Properties of *Batuan* Fruit Powder

3.2.1. Antioxidant activity. The antioxidant activity measures the ability of the *batuan* fruit powder to scavenge the stable radical DPPH. It is important to determine the antioxidant activity of the product because it is desired to know whether the product can not only satisfy the taste buds of the consumers or provide nutrients but also protect from free radicals to reduce the risk of heart disease and certain cancers. The antioxidant activity values of the samples are compared at varying SMS concentration and drying temperature (Table 6). In order to determine whether these values are competitive, the antioxidant activity values of standards 1 mM BHA and 1 mM ascorbic acid were also determined. Results show that 1 mM BHA and 1 mM ascorbic acid have DPPH-scavenging activities which are lower than the samples of *batuan* fruit powder. Hence, it may be said that the powder has a relatively high antioxidant activity. Statistical analysis shows that only the temperature, not the SMS concentration, had a significant effect on the antioxidant activity of the *batuan* fruit powder.

Table 6. Antioxidant activity (% DPPH scavenging activity) of *batuan* fruit powder at varying SMS concentration and drying temperature.

SMS CONCENTRATION (ppm)	DRYING TEMPERATURE (°C)		
	50	60	70
0	26.04 ± 0.80[a]	23.99 ± 3.21[b]	21.66 ± 0.56[c]
125	25.05 ± 1.74[a]	27.67 ± 1.72[b]	19.53 ± 1.29[c]
250	30.29 ± 1.07[a]	21.30 ± 2.33[b]	19.04 ± 0.86[c]
Standard			
1 mM BHA		10.90 ± 1.93[d]	
1 mM ascorbic acid		15.43 ± 3.57[e]	

Mean values of the same superscript for all treatments are not significantly different at $P \leq 0.05$, HSD.

Figure 13 shows the contour plots of antioxidant activity against SMS concentration and drying temperature. Higher antioxidant activity values are achieved at lower temperature and higher SMS content. This is because the antioxidants present in the powder, such as phenolics and ascorbic acid, are basically heat sensitive so that the antioxidants are easily degraded at higher temperature. A study by Ahmed *et al.* (2010) reported that the SMS was able to protect the phenolics and vitamin C in sweet potato flour such that the samples treated with SMS had higher total phenolics and vitamin C content than the control (without SMS). Also, increasing the drying temperature from 50°C to 60°C resulted in decreasing concentrations of total phenolics and vitamin C. However, both SMS concentration and temperature did not affect the β–carotene content of the sweet potato flour. Sulfite plays an important role as bacteriostat, antiseptic, and antioxidant. It also protects vitamin C present which may contribute to the fruit's antioxidant activity (Morgan and Field, 1929).

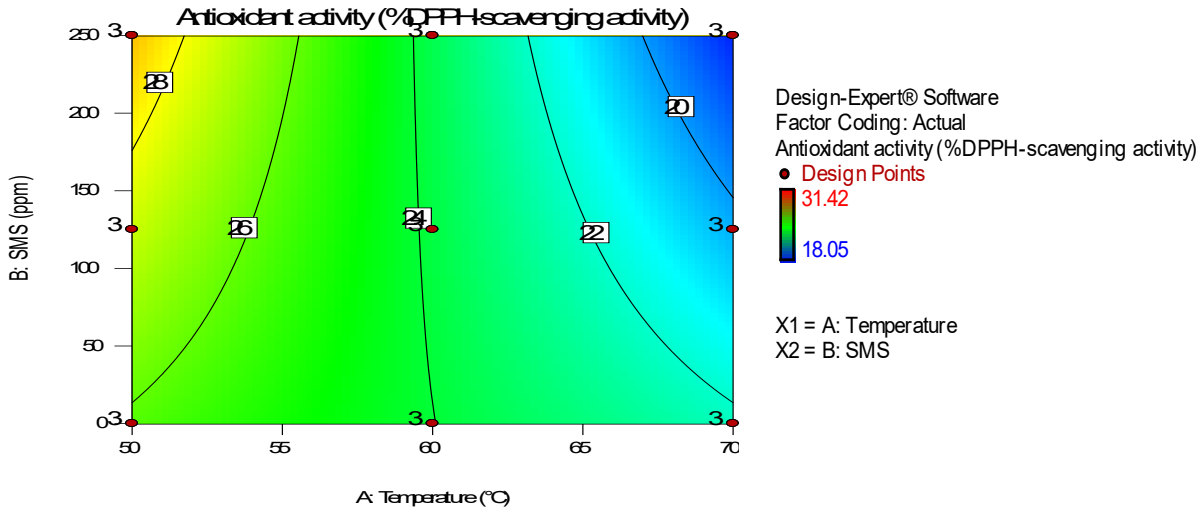

Figure 13. Contour plots of antioxidant activity of *batuan* fruit powder versus drying temperature and SMS concentration.

3.2.2. Total phenolics. The total phenolics content is usually related to the antioxidant activity of a product. In this study, gallic acid was used as a standard. The values are shown in Table 7 and Figure 14.

Table 7. Total phenolics content (µg gallic acid equivalent/mg powder) of *batuan* fruit powder at varying SMS concentrations and drying temperatures.

SMS CONCENTRATION (ppm)	DRYING TEMPERATURE (°C)		
	50	60	70
0	11.93 ± 2.65[a]	9.82 ± 2.50[a]	8.24 ± 3.33[b]
125	14.36 ± 1.13[a]	22.18 ± 3.68[a]	5.34 ± 0.83[b]
250	12.35 ± 0.98[a]	12.89 ± 0.95[a]	7.61 ± 0.80[b]

Mean values of the same superscript for all treatments are not significantly different at $P \leq 0.05$, HSD.

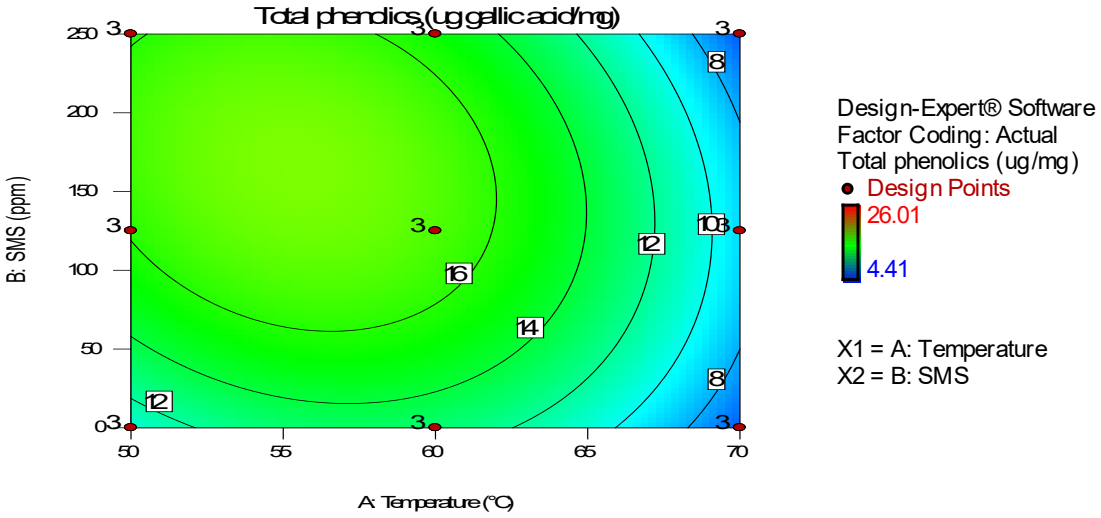

Figure 14. Contour plots of total phenolics of *batuan* fruit powder versus drying temperature and SMS concentration.

Results revealed that only the drying temperature had a significant contribution on the total phenolics content of *batuan* fruit powder. However, with combined effects of temperature and SMS concentration (Fig. 14), it is possible to identify the temperature and SMS concentration wherein a maximum total phenolics content may be predicted. Since the phenolics are heat-sensitive, it may be expected that the total phenolics was higher at lower drying temperature. The effect of SMS on the total phenolics was not significant probably because the SMS was volatile at high temperature so that the latter just escaped from the pulp during drying.

3.2.3. Water Absorption Index (WAI). WAI indicates the ability of the powder to absorb water due to the hydrophilic groups present that hold water (Narbutaite *et al.,* 2008). The WAI values are expressed as gram of sediment (equal to the sum of mass of powder and mass of water absorbed) per gram of sample. Table 8 and Figure 15 summarize the WAI values of *batuan* powder from different treatments.

Table 8. Water absorption index (g sediment/g sample) of *batuan* fruit powder at varying SMS concentration and drying temperature.

SMS CONCENTRATION (ppm)	TEMPERATURE (°C)		
	50	60	70
0	3.394 ± 0.188[a]	3.617 ± 0.271[a]	3.464 ± 0.227[a]
125	3.449 ± 0.060[a]	4.081 ± 0.018[a]	3.087 ± 0.056[a]
250	3.376 ± 0.156[a]	4.357 ± 0.410[a]	3.210 ± 0.038[a]

Mean values of the same superscript for all treatments are not significantly different at $P \leq 0.05$, HSD.

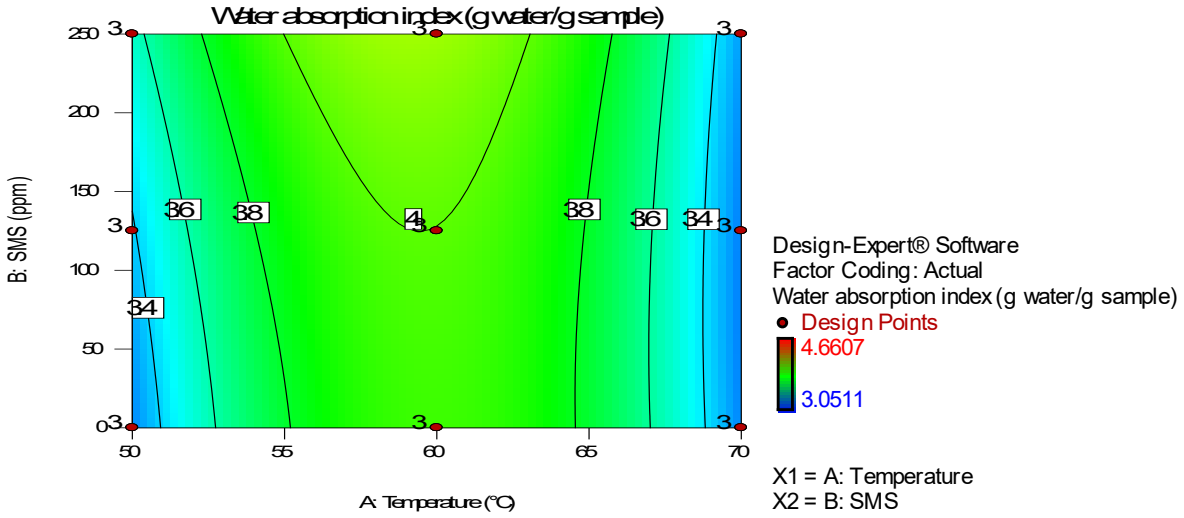

Figure 15. Contour plots of water absorption index of *batuan* fruit powder versus drying temperature and SMS concentration.

Table 8 shows that the values of WAI are not significantly different among the samples. Nevertheless, the quadratic model to express WAI as a function of SMS concentration is significant so that the model is still useful for optimization. From Figure 15, a maximum WAI may be obtained somewhere between 50°C and 70°C. The increase in WAI from 50°C to about 60°C could be due to partial gelatinization of starch and protein resulting in increased water uptake. However, above 60°C, there was higher rate of vaporization of liquids resulting in shrinkage of the polar sites and then poor absorption of moisture upon rehydration. Gunaratne and Hover (2002 as cited in Ahmed *et al.,* 2010) explained that the difference in WAI could be due to variation in the degree of engagement of hydroxyl groups to form hydrogen bonds between starch chains, and loss of starch crystalline structure.

3.2.4. Water solubility index (WSI). The water solubility index is an indication of starch degradation of the powder during drying. Table 9 and Figure 16 show the WSI values of *batuan* fruit powder at varying temperature and SMS concentration.

Table 9. Water solubility index (%) of *batuan* fruit powder at varying SMS concentration and drying temperature.

SMS CONCENTRATION (ppm)	DRYING TEMPERATURE (°C)		
	50	60	70
0	24.02 ± 1.34[a]	14.23 ± 0.41[c]	23.29 ± 1.66[a]
125	18.98 ± 0.75[b]	14.46 ± 0.37[c]	26.20 ± 1.49[a]
250	15.92 ± 1.83[b]	14.42 ± 2.37[c]	23.85 ± 1.45[a]

Mean values of the same superscript for all treatments are not significantly different at $P \leq 0.05$, HSD.

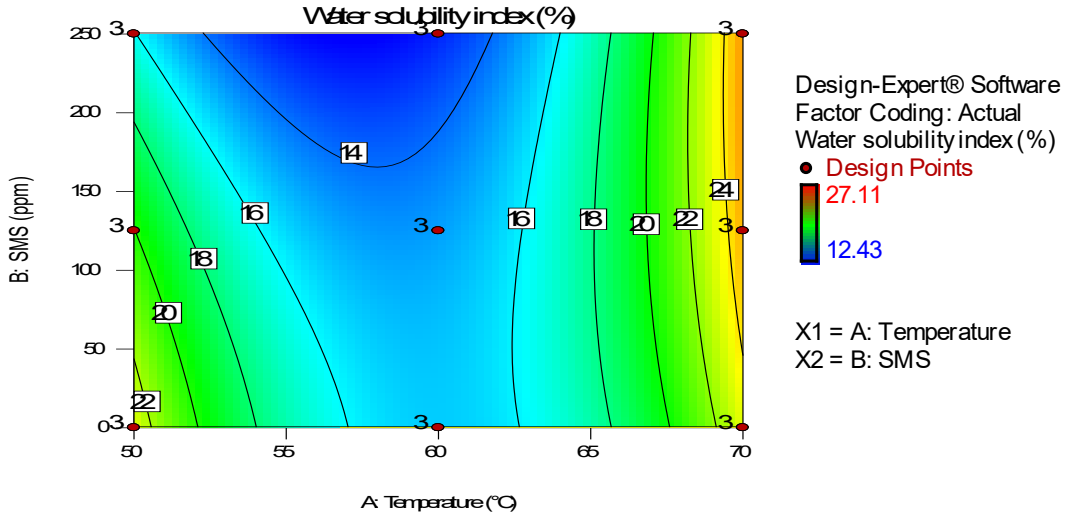

Figure 16. Contour plots of water solubility index of *batuan* fruit powder versus drying temperature and SMS concentration.

The WSI reaches a minimum value somewhere between 50°C and 70°C. Two-factor ANOVA at 5% level of significance revealed that SMS concentration and drying temperature are both significant factors that affected the WSI of the product. The model to describe the WSI of the product at varying SMS concentration and drying was also significant. However, by looking at the individual F-values, the temperature had higher value of F (32.76) than SMS concentration (8.48) which means that the temperature is the predominant factor for the variation in WSI of *batuan* fruit powder during processing.

The minimum WSI values at 60°C may be accounted to the semi-crystalline structure of starch and formation of hydrogen bonds between starch molecules. Above 60°C, the heat caused the starch molecules to swell and expose the hydrophilic groups, thereby, increasing the solubility of the powder in terms of WSI (Eliasson and Gudmundsson 1996 as cited in Ahmed *et al.* 2010). At 50°C, greater WSI values were obtained because this is where 48 hours was needed to dry the pulp. Moreover, the long drying time favored the swelling and exposure of hydrophilic groups of the starch molecules even at a slower rate.

3.3. Optimum Conditions for *Batuan* Fruit Powder

Based on the physicochemical and functional analyses, the optimum drying temperature and concentration of SMS was determined using Design-Expert® software. The physicochemical and functional properties were treated as responses and criteria for optimization. However, only those responses that have significant difference (based on Two-factor ANOVA at 5% level of significance) at varying treatments were considered. These criteria are listed in Table 10.

Table 10. Criteria for optimization of *batuan* fruit powder.

CRITERION	GOAL	IMPORTANCE	MODEL	RESULT OF ANOVA
Temperature (°C)	in range (50-70)		NA	
SMS concentration (ppm)	in range (0-250)		NA	
Whiteness index	Maximize	5	Linear	Significant
Total phenolics (mg gallic acid/g sample)	Maximize	3	Quadratic	Significant
Antioxidant activity (% DPPH-scavenging activity)	Maximize	3	2FI	Significant
Titatable acidity (g citric acid/100 g sample)	Maximize	5	Quadratic	Significant
Total soluble solids (% Brix)	Maximize	3	Quadratic	Significant
pH	None	NA	Quadratic	Not significant
Water absorption index (g sediment/g sample)	Maximize	3	Quadratic	Significant
Water solubility index (g solids/g sample)	Maximize	3	Quadratic	Significant
Bulk density (g/mL)	Maximize	3	Quadratic	Significant
Fineness modulus	None		NA	

NA – not applicable

The goal "in range" means that the optimum condition to be determined should be within the specified range. Otherwise, either "maximize" or "minimize" was selected. For example, "maximize" was chosen for whiteness index since maximum value implies lightest brown color. Hence, the determination of an optimum value involves selection of the best value for each criterion whether the latter is maximum or minimum.

The importance of a criterion was described in terms of a rating from 1 to 5 (where "5" is of highest importance). The rating of 5 was given to whiteness index because the color is the first thing that is evaluated by the consumers and hence a very important criterion. Also, since the objective of developing the product is to become an alternative souring agent, the TA was also given a rating of 5. Other factors were given 3 because it was also desired to create a product that is health beneficial (i.e., antioxidant activity, total phenolics), water soluble (i.e., water solubility index), and less spacious (i.e., bulk density).

The selection of a fit model (i.e., linear, quadratic), for the data points for each criterion, was done following the suggestion of the software. The usual options are linear, quadratic, cubic, and 2FI and the appropriate model depends on statistical analysis done by the software.

Thus, using Design-Expert® software, the optimum temperature and SMS concentration were calculated as 50.0°C and 106 ppm, respectively. Also, responses (physicochemical and functional properties) corresponding to the optimum condition were predicted by the software. However, the desirability was found to be 0.578 which is relatively low. The desirability of a response or the optimum value ranges from 0 to 1 where 0 stands for a non-acceptable value of the response and 1 where higher or lower (depending on the direction of the optimization whether maximize or minimize) values of the response have little merit (http://www.inside-r.org/packages/cran/qualityTools/docs/desirability).

The desirability of 0.578 was obtained as the geometric mean of all the individual desirability values for each response. If the goal for a certain response is to maximize its value (i.e., whiteness index), then the individual desirability approaches 1 if the obtained response is higher. Otherwise, if the goal of a response is to minimize its value (which did not happen here), then the desirability increases if the response decreases. On the other hand, if the goal is to have a target value of the response, then the desirability approaches 1 if the response is nearer to the target value

(http://www.jmp.com/support/help/Desirability_Profiling_and_Optimization.shtml). However, since the optimization of SMS concentration and drying temperature involved 8 responses (only those that were significantly affected by SMS and temperature based on ANOVA) with different goals, then the resulting optimum value, together with the desirability, would lie midway to satisfy all the responses (Kuhn, 2012). Furthermore, the desirability may score how the predicted values agree with the desired (maximum or minimum) values. For example, for whiteness index (WI), the maximum possible value that was obtained was 46.94 at 50°C and 250 ppm SMS, however, the predicted value of WI at the optimum SMS concentration and drying temperature is 46.4773 (Table 13) which is slightly lower than the maximum and may give an individual desirability near 1. On the other hand, for water absorption index, where the goal is to maximize its value, the maximum possible value is 4.357 at 60°C and 250 ppm SMS, however, the predicted value is only 3.36619 which is way below the desired value resulting in a low individual desirability. Therefore, the overall desirability of 0.578 was a result of high and low values of individual desirability. Nevertheless, since the color (in terms of WI) is one of the most important responses during optimization (where a score of 5 was given for its importance), it was observed that its predicted value was very near to the desired value. However, because the other responses were given less importance, the individual desirability for the other responses became low which consequently gave a lower overall desirability.

Nonetheless, determining the actual responses (by producing the *batuan* powder at the suggested optimum SMS concentration and drying temperature) is more important than just predicting the responses and comparing them with the desired responses.

3.4. Adoption of Predicted Optimum Conditions for *Batuan* Fruit Powder

Even with relatively low desirability, the computed optimum value was followed to produce optimized *batuan* fruit powder. The drying of *batuan* pulp (containing 106 ppm SMS) took 48 hours at 50°C (dryer could not attain the exact optimum temperature of 50.0°C) to produce the brittle dried pulp ready for grinding. After the production of the optimized product, the powder was tested for its physicochemical and functional properties to verify the predicted values as shown in Table 11.

Table 11. Predicted versus observed properties of optimized *batuan* fruit powder (50.0°C drying temperature, 106 ppm SMS).

PHYSICOCHEMICAL/ FUNCTIONAL PROPERTY	PREDICTED VALUE	ACTUAL VALUE	ERROR (%)
Whiteness index	46.4773	48.30 ± 1.51	3.77
Total phenolics (mg gallic acid/g sample)	15.6955	31.13 ± 0.90	49.58
Antioxidant activity (% DPPH-scavenging activity)	27.1375	26.04 ± 0.80	4.21
Titratable acidity (g citric acid/100 g sample)	23.8629	26.56 ± 0.61	10.15
Total soluble solids (% Brix)	4.66923	4.9 ± 0.1	4.71
pH	NA	1.58 ± 0.07	NA
Water absorption index (g sediment/g sample)	3.36619	3.0094 ± 0.1148	11.86
Water solubility index (g solids/g sample)	20.5724	21.837 ± 5.647	5.79
Bulk density (g/mL)	0.654995	0.661 ± 0.001	0.91
Fineness modulus	NA	0.70 ± 0.06	NA

NA – not applicable

Table 11 suggests that some of the observed values agree with the predicted values, such as whiteness index, antioxidant activity, TSS, WSI, and bulk density, with small percent error. On the other hand, large

percentage of error was observed in values for total phenolics. This may be a result of lack of fitness of the models during optimization. For each response, an appropriate model (i.e., linear, quadratic, cubic, 2FI), which was also suggested by the software, was needed to be established to describe its variation with SMS concentration and drying temperature. However, based on statistical analysis at 5% level of significance, except for WI and TA, the lack of fitness of most of the responses were found to be significant, meaning, the models could not satisfactorily predict the values of these responses at a given SMS concentration and drying temperature. Even so, the models were still found to be useful since they are significant based on statistical analysis and they are necessary for optimization. Nonetheless, the actual values of most of the responses (i.e., WI, total phenolics, TA, WSI, BD) were found to be better than the predicted values.

3.5. Comparison of Optimized *Batuan* Fruit Powder Against *Batuan* Fruit Pulp

To describe the drying characteristics of the optimized *batuan* fruit powder, the physicochemical and functional properties of the latter were compared with those of the wet pulp obtained after steaming and pulping (Table 12).

Table 12. Proximate composition of *batuan* fruit pulp and powder.

COMPOSITION	WET BASIS (%)		DRY BASIS (g water/g solids)	
	PULP	POWDER	PULP	POWDER
Moisture content	87.15 ± 0.10	10.75 ± 0.02	6.7849[a]	0.1205[b]
Ash	0.32 ± 0.02	2.44 ± 0.06	0.0251[a]	0.0273[a]
Crude protein	2.81 ± 0.07	0.23 ± 0.05	0.2189[a]	0.0026[b]
Crude fat	1.84 ± 0.52	3.16 ± 0.11	0.1435[a]	0.0354[b]
Crude fiber	0.45 ± 0.03	8.23 ± 0.11	0.0922[a]	0.0351[b]
NFE	7.42	75.19	0.5775	0.8425

Mean values with the same superscript within rows are not significantly different at $P \leq 0.05$, HSD.

Results show that there was no significant decrease in total ash content. However, moisture content, crude protein, crude fat, and crude fiber decrease significantly after drying.

Drying process involves the removal of water through evaporation to decrease the moisture content of food and consequently to lengthen its shelf-life. This is the main reason for the significant decrease in moisture content of the pulp samples from 87.15% to 10.75%. Decrease in crude protein content of *batuan* powder is attributed to Maillard browning that might have occurred in the sample (Saltmarch and Labuza, 1982). Proteins were used up by non-enzymatic browning by reacting with a reducing sugar to form brown compounds (melanoidins). On the other hand, the decrease in crude fat content can be attributed to lipid oxidation in powdered sample, however, the rancidity may not be pronounced due to several factors such as minute amount of crude fat in the sample, limited oxygen due to the impermeability of the packaging material to gases, and the presence of antioxidants that prevent lipid oxidation. The very low water activity of the powder beyond the monolayer value could have favored the occurrence of lipid oxidation in the powdered sample since water would not have a “protective effect” to prevent lipid oxidation, thus, lowering the crude fat content of the sample. Significant decrease in crude fiber may be credited to two main reasons: (1) curling and twisting of fibers during drying making it more prone to degradation, and (2) during sieving of pulverized sample with 60 mesh screen, incorporation of fibrous components in the reject oversize.

Aside from the proximate composition, some of the functional properties of wet pulp and powder were also compared as seen in Table 13.

Table 13. Functional properties of *batuan* fruit pulp and powder.

COMPOSITION	WET BASIS (%)		DRY BASIS (g water/g solids)	
	PULP	POWDER	PULP	POWDER
Antioxidant activity (% DPPH-scavenging activity)	27.60 ± 3.40^{a}	26.04 ± 0.80^{a}	NA	NA
Total phenolics (mg GAE/g sample)	5.58 ± 0.79	31.13 ± 0.90	0.434^{a}	0.3488^{b}

Mean values with the same superscript within rows are not significantly different at $P \leq 0.05$, HSD.
GAE – gallic acid equivalent

Table 13 shows that the antioxidant activity of the *batuan* fruit pulp remained unchanged even after drying and grinding. The total phenolics content (in wet basis), on the other hand, was found to increase after drying. However, if the total phenolics of pulp and powder are to be converted to dry basis (mg GAE/g solids), the resulting values are 0.434 and 0.3488, respectively, meaning, the amount of phenolics actually decreased during drying. The phenolics serve as antioxidants that protect the product during drying where oxidation could happen. However, for *batuan* fruit pulp, the antioxidant activity remained unchanged so that the phenolics did not play the major role as antioxidants. There may be other compounds present in the *batuan* that contributed largely to the antioxidant activity such as carotenoids which are more heat-stable than phenolics and ascorbic acid. Studies by Zhang and Hamauzu (2004) and Turkmen *et al.* (2005) show that phenolics and ascorbic acid were reduced during conventional heat treatment of selected vegetables, but the carotenoids were retained after cooking. A study by Torres *et al.* (2014) revealed that the carotenoids, although known to be nonpolar, in seaweeds, is highly soluble in methanol. The carotenoid present in the seaweeds is primarily zeaxanthin, a carotenoid alcohol that is heat stable, which is a powerful antioxidant in fruits and vegetables. This implies that the *batuan* fruit may contain significant amount of zeaxanthin that primarily affects the antioxidant activity of the fruit, however, detection and quantification of such compound is beyond the scope of this study.

4. CONCLUSION

During the production of *batuan* fruit powder, the procedure was established and the process conditions were optimized. The drying temperature was set at 50°C, 60°C, and 70°C, while the concentration of SMS in the wet pulp was varied at 0, 125 ppm, and 250 ppm. The optimum temperature and SMS concentration were determined using Design-Expert® software where the physicochemical and functional characteristics of the powder were considered as the responses. Hence, the optimum temperature and SMS concentration were found to be 50.0°C and 106 ppm, respectively, with a desirability of 0.578. The optimum conditions were used to produce the powder, and the powder was evaluated again of its physicochemical and functional properties.

ACKNOWLEDGMENT

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5:15 PM - 5:30 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Hall A)

[4-1600-A-06] Effect of Processing Conditions on Bioactive Compounds and Antioxidant Activities of Tea Infusion

*Wei Qin[1], Sunantha Ketnawa[1], Florencio, Jr. Collado Reginio[1,2], Ryutaro Yamada[3], Takuya Araki[3], Yukiharu Ogawa[1] (1. Graduate School of Horticulture, Chiba University.(Japan), 2. Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baños(Philippines), 3. Institute of Fruit Tree and Tea Science, NARO(Japan))

Keywords: Antioxidant activities, Bioactive compounds, Coarse kneading, Japanese green tea, Tea processing

The manufacturing process of Japanese green tea consists of six steps, which are followed by steaming, coarse kneading, crumpling, secondary kneading, precise kneading and drying. Coarse kneading (CK) is the first step of processing to destroy the structure of tea leaf at a certain temperature. Previous studies have shown that coarse kneading have the greatest impact on green tea quality during tea processing. However, few studies to date have provided information regarding the effects of coarse kneading on tea quality during the Japanese green tea manufacturing process. Thus, this study aimed to investigate the effects of processing conditions in coarse kneading step on bioactive compounds and antioxidant activities in tea infusion. The first flush fresh tea leaves were harvested at the experimental field of the national agriculture and food research organization (NARO) in Shizuoka, Japan in May 2019, and were processed continuously with different CK temperatures (34, 36 and 38 ˚ C). The sample tea leaves were collected at each processing step and immediately cooled in a refrigerator. The processed tea leaves at each step were infused by hot distilled water at 95 ˚ C for 5 min to examine bioactive compounds (total polyphenol content (TPC), total flavonoid content (TFC), and chlorogenic acid content (CA)) and antioxidant activities (1,1-diphenyl-2-picrylhydrazyl (DPPH) and 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid (ABTS) radical scavenging activity, ferric-reducing antioxidant power (FRAP) and metal ion chelating activity (MIC)). The results showed that bioactive compounds (TPC, TFC and CA) of tea infusion increased with increasing CK temperature. The values of the antioxidant activities of the tea infusion also showed a positive correlation to CK temperatures. ABTS and MIC trend of tea infusions showed the same trend as bioactive compounds as well as they were the highest at 38 ˚ C CK. However, DPPH and FRAP values of tea infusions produced from 36 and 38 ˚ C CK did not follow the same trend demonstrating higher of those value of 36 ˚ C than those of 38 ˚ C. In general, antioxidant activities trend of 38 ˚ C tea infusion was more stable than those of 34 and 36 ˚ C during the tea manufacturing process. These results indicate that coarse kneading temperature during green tea processing have a positive effect on the increase in the bioactive compounds of tea infusion and the stability of the antioxidant activities.

5:30 PM - 5:45 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Hall A)

[4-1600-A-07] *In Vitro* Release Characteristics of Sugars and Hydrolysis of Starch During Simulated Digestion of Saba banana at Different Maturity Stages

*Florencio, Jr. Collado Reginio[1,2], Wei Qin[1], Yukiharu Ogawa[1] (1. Graduate School of Horticulture, Chiba University(Japan), 2. Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baños(Philippines))

Keywords: maturity, starch digestibility, viscosity, sugars

Saba banana [*Musa* ‘*saba*’ *(Musa acuminata x Musa balbisiana)*] is one of the most popular fruit crops in terms of production and trade in the Philippine food industry. It has a wide range of applications in the domestic market and is also known to offer great nutritional and health benefits. However, restriction of banana consumption as desserts or snacks is suggested as it also contains higher amounts of carbohydrates compared to other fruits. The determination of bioavailable carbohydrate in a given product is necessary to predict its effect on postprandial blood glucose response. Thus, this study was conducted to examine the changes in sugar and starch fractions of Saba banana during simulated *in vitro* gastrointestinal digestion. Five maturity stages of Saba banana were identified based on peel color index (1, all green; 2, green but turning yellow; 3, greenish yellow; 4, yellow with green tips; and 5, yellow with brown flecks). Unhomogenized cut and homogenized slurry samples representing intact tissue and structure-less states of Saba banana were obtained in each maturity stage and evaluated for starch hydrolysis rates. Physicochemical properties during maturation, and release characteristics of sugars (sucrose, fructose, and glucose) and viscosity of digesta during *in vitro* digestion were also determined. The decrease in total starch content was an indication that starch degradation occurred during ripening. More than 70% of resistant starch was degraded from unripe to overripe stage. During the course of digestion, a significant decrease in sucrose was observed whereas glucose and fructose contents increased concomitantly. The highest starch hydrolysis (%) for both homogenized and unhomogenized states was determined in unripe stages and a decreasing trend was observed as maturity advanced. The higher digesta viscosity values of ripe stages than unripe counterpart could influence its susceptibility to digestion by reducing the extent of mixing and the interaction with digestive enzymes. Additionally, comparing the two states, the unripe stages of homogenized slurry samples were found to have significantly higher percent starch hydrolysis and shorter digestion time than unhomogenized cut samples owing to the difference in structure. These results provide an understanding of the different factors that significantly impact starch digestibility during maturation of Saba banana.

5:45 PM - 6:00 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Hall A)

[4-1600-A-08] *In Vitro* Examination of Starch Digestibility and Antioxidant Activities of Amaranth Grains

*Xiaoyan Xiong[1], Florencio Jr. Collado Reginio[1,2], Sukanya Thuengtung[1], Sunantha Ketnawa[1], Yukiharu Ogawa[1] (1. Graduate School of Horticulture, Chiba University(Japan), 2. Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baños(Philippines))
Keywords: Amaranth grain, In vitro digestion, Antioxidant activities

Amaranth grain is a pseudo-cereal crop which is rich in both macro- and micronutrients. Apart from having high starch content, the phytochemicals in amaranth grains are abundant especially phenolic acids. In this study, the digestibility of starch in amaranth was examined by means of an *in vitro* simulation and the total phenolics, flavonoids, and antioxidant activities of two different solvent extracts from raw and cooked grains were determined. Whole grain and slurry states of cooked amaranth were subjected to simulated *in vitro* gastrointestinal digestion and starch hydrolysis (%) was computed based on the free glucose content of the digested fractions collected at different time periods. Additionally, raw and cooked whole amaranth grains were evaluated for their total phenolic content (TPC), total flavonoid content (TFC) and antioxidant activties (ferric reducing antioxidant power [FRAP], DPPH and ABTS free-radical scavenging activity, and metal ion chelating [MIC] activity) using sodium phosphate buffer (100mM, pH 7.4) and 80% (v/v) methanol as extracting solvents. Results showed that after 360 min of *in vitro* gastrointestinal digestion, the whole grain cooked amaranth grain showed a relatively lower starch hydrolysis (66.82±1.60%) than the slurry state

(80.44±3.91%)., This was accounted to the differences in morphological structure. It was also found that raw amaranth grain showed higher TPC, TFC, and antioxidant activity values when compared to cooked grain, except for DPPH, and these phenolic compounds were released more in sodium phosphate buffer than in methanol solvent possibly due to more water-soluble compounds of the grain. The results indicated that amaranth grain could be regarded as a healthy food as it can be a potential source of natural antioxidant and, at the same time, whole amaranth grain could help in controlling blood glucose level changes because of its slow rate of digestion.

Oral Session | Postharvest/Food Technology and Process Engineering
[4-1600-A] Postharvest/Food Technology and Process Engineering (3)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Hall A (Main Hall)

[4-1600-A-09] Effects of Cell Structure Changes of Citrus Peel on the Digestibility of Intracellular Antioxidants during *in vitro* Digestion

*Yidi Cai[1], Yukiharu Ogawa[1] (1. Graduate School of Horticulture, Chiba University(Japan))

Keywords: Plant foods, Bioavailability, Antioxidant activity, In vitro, Structural attributes

Plant foods are essential foods in human diets. Vegetables and fruits contain a lot of antioxidants which can reduce the risk of some chronic diseases. In most cases, food processing during industrial or household meal preparation may result in microstructural changes and significant loss of natural antioxidants. Assessing the impact of food processing on the release of natural antioxidants during digestion is a critical factor for maintaining and improving its bioavailability. In this study, relationship between structural changes of plant cell and changes in antioxidant potential during *in vitro* digestion was investigated using four particle sizes of freeze-dried citrus peel powder. These were regarded as plant cell models with various degree of cell damage. Simulated *in vitro* gastrointestinal digestion was conducted and digested fractions were taken at different digestion times. The supernatant fractions were used to evaluate the total polyphenol content [TPC] and antioxidant activity (DPPH-radical scavenging activity and ferric reducing antioxidant power [FRAP]). Results showed that the antioxidant potential of digested fractions during *in vitro* digestion was approximately decreased with decreasing powder size. Moreover, DPPH and FRAP activities of all sample in the gastric digestion stage showed higher values than that of small intestinal stage. In the contrary, TPC showed high values in the small intestinal phase of digestion. These results suggest that the release of antioxidant compounds in plant foods during digestion could be related to their structural attributes such as cell damages, which can be affected by different processing conditions.

Effects of Cell Structure Changes of Citrus Peel on the Digestibility of Intracellular Antioxidants during *in vitro* Digestion

Yidi Cai[1], Yukiharu Ogawa[1]*
[1]Graduate School of Horticulture, Chiba University, Japan

*Corresponding author: ogwy@faculty.chiba-u.jp

ABSTRACT

Plant foods are essential foods in human diets. Vegetables and fruits contain a lot of antioxidants which can reduce the risk of some chronic diseases. In most cases, food processing during industrial or household meal preparation may result in microstructural changes and significant loss of natural antioxidants. Assessing the impact of food processing on the release of natural antioxidants during digestion is a critical factor for maintaining and improving its bioavailability. In this study, relationship between structural changes of plant cell and changes in antioxidant potential during *in vitro* digestion was investigated using three particle sizes of freeze-dried citrus peel powder. These were regarded as plant cell models with various degree of cell damage. Simulated *in vitro* gastrointestinal digestion was conducted and digested fractions were taken at different digestion times. The supernatant fractions were used to evaluate the total polyphenol content [TPC] and antioxidant activity (DPPH-radical scavenging activity and ferric reducing antioxidant power [FRAP]). Results showed that the antioxidant potential of digested fractions during *in vitro* digestion was approximately decreased with decreasing powder size. Moreover, DPPH and FRAP activities of all sample in the gastric digestion stage showed higher values than that of small intestinal stage. In the contrary, TPC showed high values in the small intestinal phase of digestion. These results suggest that the release of antioxidant compounds in plant foods during digestion could be related to their structural attributes such as cell damages, which can be affected by different processing conditions.

Keywords: Plant foods, Bioavailability, Antioxidant activity, *In vitro*, Structural attributes, Cell damage

Oral Session | Postharvest/Food Technology and Process Engineering

[4-1600-C] Postharvest/Food Technology and Process Engineering (4)

Chair:Kornkanok Aryusuk(King Mongkut's University of Technology Thonburi, Thailand), Itaru Sotome(University of Tokyo, Japan)

Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room C (3rd room)

[4-1600-C-01] Estimation of Moisture Loss of Cucumber during Storage using CFD Simulation based on Heat and Mass Transfer Model

*Seong-Heon Kim[1], Chinatsu Nishihara[1], Fumina Tanaka[1], Fumihiko Tanaka[1] （1. Kyushu Univ.(Japan)）

4:00 PM - 4:15 PM

[4-1600-C-02] Screening (*in vitro*) The Inhibition Effect of Generally Recognized As Safe (GRAS) Substances on The Postharvest Fungal Pathogens and Its Modelling

*Passakorn Kingwascharapong[1], Supatra Karnjanapratum[2], Fumina Tanaka[1], Fumihiko Tanaka[1] （1. Kyushu University(Japan), 2. King Mongkut's Institute of Technology Ladkrabang(Thailand)）

4:15 PM - 4:30 PM

[4-1600-C-03] Modeling The Ripening Behavior of Mature Green Tomato at Different Storage Temperatures

*Drupadi Ciptaningtyas[1,2], Wakana Kagoshima[3], Rei Iida[1], Hitomi Umehara[1], Masafumi Johkan[1], Takeo Shiina[1] （1. Graduate School of Horticulture, Chiba University(Japan), 2. Faculty of Agro-industrial Technology, Universitas Padjadjaran(Indonesia), 3. Faculty of Horticulture, Chiba University(Japan)）

4:30 PM - 4:45 PM

[4-1600-C-04] Quality and Shelf-life Prediction of Fresh-cut ‘Phulae’ Pineapple by Using Image Analysis and Artificial Neural Networks

*Rattapon Saengrayap[1], Mayura Dongsuea[1] （1. Postharvest Technology and Logistics Program, School of Agro-Industry, Mae Fah Luang University(Thailand)）

4:45 PM - 5:00 PM

[4-1600-C-05] Stationary Machine Vision Based Real-Time Estimation of Japanese Black Cattle Serum Vitamin A using Eye Fundus Color

*SAMUEL OUMA OTIENO[1], Naoshi Kondo[1], Tateshi Fujiura[1], Yuichi Ogawa[1], Tetsuhito Suzuki[1], Katsuya Takenouchi[1], Hidetsugu Yoshioka[1], Moriyuki Fukushima[2], Takahiko Ohmae[3] （1. Graduate School of Agriculture, Kyoto University(Japan), 2. Hyogo Prefectural Hokubu Agricultural Institute(Japan), 3. Tajima Agricultural High school(Japan)）

5:00 PM - 5:15 PM

[4-1600-C-06] Segmentation of common scab lesion on intact potatoes using single near-infrared image

*Dimas Firmanda Al Riza[1,2], Kazuya Yamamoto[3], Kazunori Ninomiya[3], Tetsuhito Suzuki[1], Yuichi Ogawa[1], Naoshi Kondo[1] （1. Laboratory of Biosensing Engineering, Graduate School of Agriculture, Kyoto University, Kitashirakawa 6068267, Kyoto(Japan), 2. Department of Agricultural Engineering, Faculty of Agricultural Technology, University of Brawijaya, Jl. Veteran 65145, Malang(Indonesia), 3. Product Planning Department,

Shibuya Seiki Co., Ltd. 2200, Minamiyoshida, Matsuyama, Ehime, 791-8042(Japan))

5:15 PM - 5:30 PM

[4-1600-C-07] Myanmar Mango Maturity Prediction Based on Skin Color Using Machine Vision System

*RULIN CHEN[1], Dimas Firmanda Al Riza[1], Thwe Thwe Tun Naw[2], Phyu Phyu Leiyi[2], Aye Aye Thwe[2], Khin Thida Myint[1], Yuichi Ogawa[1], Tetsuhito Suzuki[1], Naoshi Kondo[1] (1. Kyoto University(Japan), 2. Yezin Agricultural University(Myanmar))

5:30 PM - 5:45 PM

[4-1600-C-08] Measurement of Chicken Eggshell Optical Properties Using Terahertz Spectroscopy

*Alin Khaliduzzaman[1,3], Keiji Konagaya[1], Tetsuhito Suzuki[1], Ayuko Kashimori[2], Naoshi Kondo[1], Yuichi Ogawa[1] (1. Graduate School of Agriculture, Kyoto University(Japan), 2. NABEL Co., LTd.(Japan), 3. Department of Food Engineering and Technology, Sylhet Agricultural University(Bangladesh))

5:45 PM - 6:00 PM

[4-1600-C-09] Application of LCA (Life Cycle Assessment) Methodology in Bioethanol Production from Sugar Industry Wastewater (Molasses) – A Case Study in West Java Province, Indonesia

*Agusta Samodra Putra[1,2], Ryozo Noguchi[3], Tofael Ahamed[3] (1. Graduate School of Life and Environmental Sciences, University of Tsukuba(Japan), 2. Research Center for Chemistry, Indonesian Institute of Sciences(Indonesia), 3. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan))

6:00 PM - 6:15 PM

4:00 PM - 4:15 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room C)

[4-1600-C-01] Estimation of Moisture Loss of Cucumber during Storage using CFD Simulation based on Heat and Mass Transfer Model

*Seong-Heon Kim[1], Chinatsu Nishihara[1], Fumina Tanaka[1], Fumihiko Tanaka[1] (1. Kyushu Univ.(Japan))
Keywords: Cucumber, Heat and mass transfer, Moisture content, Postharvest, Storage

Maintaining the quality of perishable products that contain high moisture is considered as one of the primary goals to extend their shelf life in the postharvest process. Cucumber is one of the popular fruits due to its unique flavor and crunchy texture, and also a perishable product. In addition, cucumber fruit is mostly consumed raw, without cooking. As the fruit consists of approximately 95% of moisture, cucumber is prone to lose easily its marketability depending on storage conditions. This study was conducted to simulate the heat and mass transfer phenomena of Japanese cucumber during storage using mathematical equations based on drying model to predict the amount of moisture releasing from the fruit, and presented a useful guideline for cucumber storage. The mathematical models were developed based on heat and mass transfer phenomena and were appropriately modified for storage condition. A 3D geometry of cucumber was reconstructed by using an X-ray CT scanner. The simulation was carried out using COMSOL software. To verify the model, the actual data, such as the changes in moisture content for 8 days under 4 different environmental conditions and temperature for 100 minutes under 2 different conditions, were investigated and then compared with the simulated data. As a result, the accuracy of the simulation of moisture ratio and temperature change was estimated at approximately 0.4% and 0.4˚ C in average RMSE, respectively. This study would be helpful for designing the optimal postharvest process and creasing economic profits on food storage.

4:15 PM - 4:30 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room C)

[4-1600-C-02] Screening (*in vitro*) The Inhibition Effect of Generally Recognized As Safe (GRAS) Substances on The Postharvest Fungal Pathogens and Its Modelling

*Passakorn Kingwascharapong[1], Supatra Karnjanapratum[2], Fumina Tanaka[1], Fumihiko Tanaka[1] (1. Kyushu University(Japan), 2. King Mongkut's Institute of Technology Ladkrabang(Thailand))
Keywords: GRAS, B.cinerea, modeling

Botrytis cinerea is one of ubiquitous fungal pathogens, mainly found in several kinds of citrus fruits and stone fruits. The use of mathematical models for quantifying and predicting microbial density has gained increasing attention because it is useful to assess biological hazards in human and animal healthcare. This study aimed to screen the effect of GRAS (Generally Recognized As Safe) substances (sodium benzoate, sodium propionate and sodium dehydroacetate) on the inhibition of mycelium growth (diameter: mm) of pathogenic fungi, *Botrytris cinerea, in vitro* study, and also to model the efficacy of antifungal activity of GRAS substances by using mathematical models. The influence of GRAS substances at different concentrations (0.1-2%) was used to evaluate antifungal activity. Sodium dehydroacetate at 0.1% showed the highest effectiveness in inhibition *B. cinerea* than the other substances at 25º C during 45 days of incubation. Three mathematic models, including modified logistic model, modified Gompertz model, and Baranyi and Robert model, were employed to predict the growth curve of *B. cinerea* treated with sodium propionate, where the root mean squares error (RMSE) and R^2 were employed to evaluate the performance of each model. The modified

logistic model showed the highest performance with the satisfactory statistical indices (highest R^2 and lowest RMSE) which indicated the better fit than other models. It can be concluded that sodium dehydroacetate is a potential GRAS substance in inhibiting *B. cinerea* and modified logistic model is a useful model to evaluate the mold growth under the various concentrations of sodium propionate treatment.

4:30 PM - 4:45 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room C)

[4-1600-C-03] Modeling The Ripening Behavior of Mature Green Tomato at Different Storage Temperatures

*Drupadi Ciptaningtyas[1,2], Wakana Kagoshima[3], Rei Iida[1], Hitomi Umehara[1], Masafumi Johkan[1], Takeo Shiina[1]
（1. Graduate School of Horticulture, Chiba University(Japan), 2. Faculty of Agro-industrial Technology, Universitas Padjadjaran(Indonesia), 3. Faculty of Horticulture, Chiba University(Japan)）
Keywords: mature green stage, modeling, red color development, ripening, tomato

Mature green tomato is a tomato that is physiologically mature but pre-ripe and has a green and slightly white color in appearance. In many countries except Japan, tomatoes are harvested in the mature green stage of development for commercial purpose. Some researcher recommends the mature green stage of development for the harvesting time of typically red tomato. It was studied that harvesting tomato at the mature green stage can extend the shelf life of the tomato which is desirable in the long-distance distribution and long-term storage. The previous study has proven that even though every individual tomato that was stored at the same storage temperature has a different onset in the ripening indicator, but the trend was almost the same and it is possible to make a model of it. This study was aimed to observe the red color development of mature green tomato during ripening while the lag time of red color development for tomato stored at different storage temperature conditions was being observed. Furthermore, the standard curve for predicting the red color development based on the storage period of mature green tomato (cv. Momotaro York) at different storage temperature will also be developed. Five storage temperatures (12, 15, 20, 25, and 30 ° C) were assigned to hold 5 tomatoes (cv. Momotaro York), respectively until every tomato reached the fully ripening stage. Red color development was determined by measuring the CIE a* value of 7 spots in the surface area of the tomato. Lag time will be determined based on the breaker stage of development of the tomato. The rate of red color development will be determined by the curve showing the relationship between the CIE a* value and storage period. Furthermore, the standard curve for predicting the red color development will be developed according to the relationship between CIE a* value and storage period that was approached by the curve fitting method to sigmoid function. The preliminary study showed that the lag time of tomato was a temperature dependent. The higher the temperature, the shorter the lag time and vice versa. This trend was also observed for the rate of red color development. By using these data including the data from the ongoing experiment, standard curves of red color development of mature green tomato during ripening at different storage temperature conditions will be developed. It will enable us to simply predict the ripening stage of tomato harvested at the mature green stage based on the temperature and storage period.

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[4-1600-C] Postharvest/Food Technology and Process Engineering (4)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room C (3rd room)

[4-1600-C-04] Quality and Shelf-life Prediction of Fresh-cut 'Phulae' Pineapple by Using Image Analysis and Artificial Neural Networks

*Rattapon Saengrayap[1], Mayura Dongsuea[1] (1. Postharvest Technology and Logistics Program, School of Agro-Industry, Mae Fah Luang University(Thailand))

Keywords: Browning index, Fractal dimension, Image features, Image processing, Storage

The image analysis technique had been applied for determining quality of fruit as a low cost, fast, and effective technique. In this study, the extracted image features, i.e., color, size, and texture, were then used as a criterion for predicting fresh-cut fruit quality and shelf-life. The aim of this study was to develop the suitable artificial neural network (ANN) model for predicting quality and shelf-life of fresh-cut 'Phulae' pineapple by using the information from image analysis. A green-yellow maturity stage of 'Phulae' pineapple [*Ananas comosus* (L.) *Merr.*] were cut into a cubical shape of 2×2×2 cm^3 and stored at 5 and 10˚C for 0, 2, 4, 6, and 8 days. The color (CIELAB values), shrinkage coefficient and firmness of fresh-cut 'Phulae' pineapple were determined every two days. The results showed that a higher storage temperature had a strong influence on the change of color. The *L** values decreased since browning occurred resulted in the increased of browning index (BI). Moreover, the greater storage temperature also influenced the higher change of fruit shrinkage and firmness. The texture of the fresh-cut pineapple became softer and shrinkage was obviously observed as storage time increased. On the other hand, the image analysis technique was also used to assess the quality of fresh-cut 'Phulae' pineapple. The change of RGB color values, fruit dimension, and fractal dimension (FD) value were determined. The results showed that the R (red) value increased as the browning occurred. Moreover, a large variation of browning intensity and its area on the pineapple surface resulted in a larger FD value. The multi-layer feed-forward back propagation ANNs were developed to predict quality and shelf-life of fresh-cut 'Phulae' pineapple. The inputs of the model were storage temperature, fruit dimension, R and FD values, while the outputs were BI, shrinkage coefficient, and shelf-life. The numbers of the hidden node in a hidden layer were varied from two to forty with the increment of two. According to the selection of the best model for predicting the quality and shelf-life, the 18 hidden-node architecture was the most suitable model which provided R^2 of 0.98 and mean square error (MSE) of 0.01, 0.002 and 0.2 day for BI, shrinkage coefficient, and shelf-life, respectively.

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Rattapon Saengrayap*, Mayura Dongsuea

Postharvest Technology and Logistics Program, School of Agro-Industry, Mae Fah Luang University, Thailand

*Corresponding author: rattapon.sae@mfu.ac.th

ABSTRACT

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Keywords: Browning index, Fractal dimension, Image features, Image processing, Storage

1. INTRODUCTION

'Phulae' pineapple [*Ananas comosus* (L.) *Merr.*] is one of the economical plants in Chiang Rai province. In a recent year, 'Phulae' pineapple has the highly domestic and oversea demand, especially an enormous Chinese market. Fresh-cut produces tend to satisfy the needs of consumer for a freshly convenient prepared food (Sillani & Nassivera, 2015). However, the fresh-cut produces may suffer with a rapid decrease of a quality, especially, their appearance, texture, and flavor (Hurling and Shepherd, 2003; Salvador et al., 2007; Wu and Sun, 2013; Allegra et al., 2015). To ensure the quality attributes of product, the quality evaluation techniques are concerned. Non-destructive evaluation is proposed as an alternative method to assess the quality without any invasive to product. Image analysis has been archived to estimate the external appearances such as size, shape and color of agricultural products (Hussain, Pu, & Sun, 2018; Moreda, Ortiz-Cañavate, García-Ramos, & Ruiz-Altisent, 2009).

In fresh-cut produce, image analysis techniques have been developed for assessing product quality and shelf-life (Pace et al., 2014; Cáez Ramírez et al., 2017; Cavallo et al., 2018). Image features extracted from the digital image were used as a key information for estimating product quality, i.e., color (Gomes et al., 2014; El-Bendary et al., 2015; Mohammadi et al., 2015), size (Moreda et al., 2009; Opara and Pathare, 2014; Ullah et al., 2018; Calixto et al., 2019), shape (Mollazade, Omid, & Arefi, 2012; Yang, Zhang, Zhai, Pang, & Jin, 2019), and texture (Borah, Hines, & Bhuyan, 2007; Pongmalai, Devahastin,

Chiewchan, & Soponronnarit, 2015; R. Quevedo, Pedreschi, Bastias, & Díaz, 2016; Roberto Quevedo, Díaz, Caqueo, Ronceros, & Aguilera, 2009).

Artificial neural network (ANN) model has been extensively achieved as a prediction tool in many studies. This is because of its ability to learn a non-linear complex relationship between input and output. The application of ANN has been found in a various fields, including crops yield prediction (Naroui Rad, Ghalandarzehi, & Koohpaygani, 2017; Naroui Rad, koohkan, Fanaei, & Pahlavan Rad, 2015; Soares, Pasqual, Lacerda, Silva, & Donato, 2013), fresh produce quality estimation (Sanaeifar, Bakhshipour, & de la Guardia, 2016; Zarifneshat et al., 2012), grading and sorting (De Oliveira, Leme, Barbosa, Rodarte, & Alvarenga Pereira, 2016; Mollazade et al., 2012; Wan, Toudeshki, Tan, & Ehsani, 2018), etc. ANN has also been reported to use for shelf-life estimation of fruits and vegetables (Mohi Alden, Omid, Rajabipour, Tajeddin, & Soltani Firouz, 2019; Sanaeifar et al., 2016), however, the information were still limited.

Therefore, in this study, the image analysis was proposed as a tool for extracting important quality information from the digital image. The image features, i.e., color, size, and texture, were used as the inputs for developing the ANN model. The objective of this study was to develop the suitable ANN model for predicting quality and shelf-life of fresh-cut 'Phulae' pineapple by using the information from image analysis.

2. MATERIALS AND METHODS

A green-yellow maturity stage of 'Phulae' pineapple [*Ananas comosus* (L.) *Merr.*] was harvested at Nanglae district, Chiang Rai Province, Thailand. Pineapple fruits were graded with the criteria of 50% yellow peel colored and the uniform size of 250-300g. The fruits then thoroughly washed, peeled, and removed the eye of the fruit. The peeled pineapples cut into a cubical shape of 2×2×2 cm^3. The cut fruits were packed into the Styrofoam trays covered with plastic wrap and stored at 5 and 10°C prior to determine the qualities at day 0, 2, 4, 6, and 8.

2.1 Quality Determination

2.1.1 Color

Color of 'Phulae' pineapples were evaluated by colorimeter (MiniScan EZ, USA) with settings standard based on illuminant/Observer of D65/10º. The CIELAB values, i.e., lightness (L^*), redness (a^*), and yellowness (b^*) were measured and recorded using Easy Match QC 4.70 software (version 2.2, USA) from three different positions. The change of fresh-cut pineapple color was reported in terms of browning index (BI) that calculated using the following equation:

$$BI = [100(x - 0.31)/0.71] \quad (1)$$

where $x = (a^* + 1.75L^*)/(5.645L^* + a^* - 3.012b^*)$

2.1.2 Shrinkage

Shrinkage of fruit was determined using toluene displacement method (Saengrayap et al., 2014) and reported in terms of shrinkage coefficient. Three pieces of cut pineapple were soaked into toluene that the weight was prior measured. Recording the change in weight of toluene, then calculated volume of product by the following equation:

$$V = m/\rho \quad (2)$$

where V is volume of fresh-cut pineapple (m^3), m is weight of toluene (kg) and ρ is density of toluene (862.27 kg/m^3). Then, the shrinkage coefficient was calculated using the following equation:

$$\textit{Shrinkage coefficient } (SC) = 1-(V/V_0) \quad (3)$$

where V is the volume of fresh-cut pineapple (mm^3) and V_0 is the initial volume of fresh-cut pineapple at day 0 (mm^3).

2.1.3 Firmness

Firmness of fresh-cut pineapple was measured as puncture force by a texture analyzer (TA-XT Plus; Stable Micro Systems, UK) using 2 mm cylindrical probe. The speed of 0.5 mm/s and penetration distance of 3 mm was used to measure the samples. The maximum force values (N) were reported from the mean value of three replicates.

2.2 Image Analysis

2.2.1 Image Acquisition

A lightbox with installed LED lamp (Philips, TL-D Deluxe, natural day light 18W) was used for imaging. The images were snapped from top of the box with the distance of 50 cm between sample and camera lens. The DSLR camera (Canon EOS – 450D, Tokyo, Japan) was used for capturing image with a

manual mode, auto focus, lens aperture at f 8.0, with 1/50 shutter speed and ISO 200. The original image files (4,288×2,848 pixels) were saved into JPEG format with the resolution of 300 dpi.

2.2.2 Image Pre-processing

Image analysis was performed by using 'ImageJ' software (version 1.51j8, NIH, Bethesda, MD, USA). The original images were cropped and resized in 400×600 pixels then whole background and noises were removed prior to analyze.

2.2.3 Color

RGB color values were extracted from pineapple images and then converted into CIELAB using color CIE standard equations (León, Mery, Pedreschi, & León, 2006). The performance for the use of image analysis and the total color difference (ΔE) were then calculated. The converted CIELAB values were then compared with the actual values obtained from colorimeter by using the following equation:

$$\Delta E = [(L_c^*-L^*) + (a_c^*-a^*) + (b_c^*-b^*)]^{1/2} \quad (4)$$

where L^*, a^*, and b^* were the actual lightness, redness and yellowness value from colorimeter, and L_c^* a_c^*, and b_c^* were the converted lightness, redness, and yellowness values.

Simple linear regressions were calculated to analyze the relationship by using correlations between converted CIELAB and colorimeter CIELAB. The RGB values were also determined a relationship between among CIELAB value using Pearson's correlation coefficient analysis at significant level ($P < 0.01$).

2.2.4 Dimension

Dimensions of fruit were determined by using 'analyze particle' function. The cropped RGB images were converted into gray scales and binary images. The major and minor dimensions were then determined and reported in the unit of mm.

2.2.5 Fractal Dimension

Fractal dimension (FD) values were determined by converting cropped RGB images into 8-bit gray scale images. The surface plot of the 8-bit gray scale images was performed to see the intensity of browning incidence. The images were then converted into a binary image prior to determine FD values. A box counting method was applied for determining FD values (Roberto Quevedo et al., 2009).

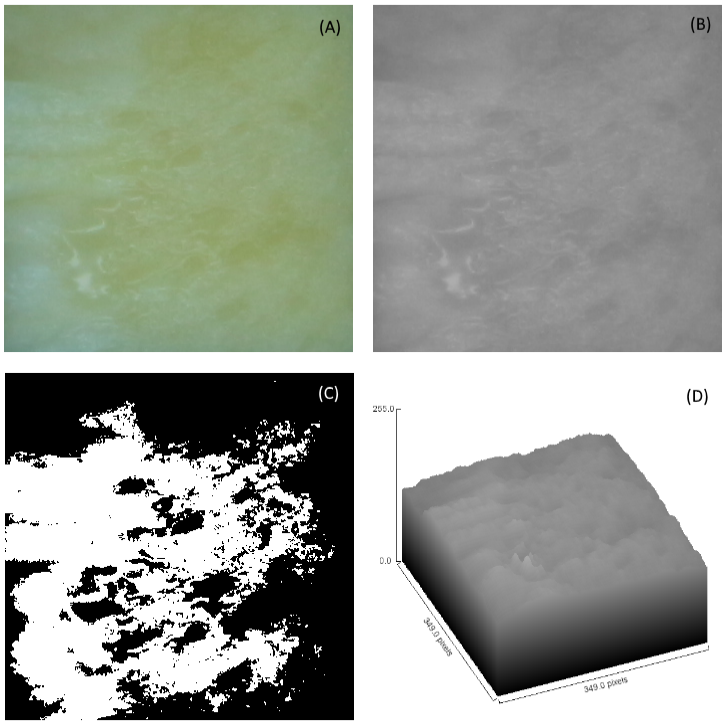

Figure 1. Image analysis procedure for FD determination: (A) — cropped RGB image; (B) — gray scale image; (C) — binary image; and (D) — surface plot.

2.3 ANN Development

ANN modelling was performed for quality and shelf-life prediction by using R (version, 3.5.0, 64 bits) and RStudio (version, 1.1.447) software. The one hidden layer feed forward back propagation architecture ANN was developed. Five different characteristics including storage temperature (T), fruit dimension (D), red (R) and FD values (FD) were used as inputs, while browning index (BI), shrinkage coefficient (SC), and shelf-life (t) was assigned as output. Moreover, the different numbers of hidden node were also tested (2-40 nodes with the increment of 2). The typical diagram of the developed ANN is shown in Figure 2

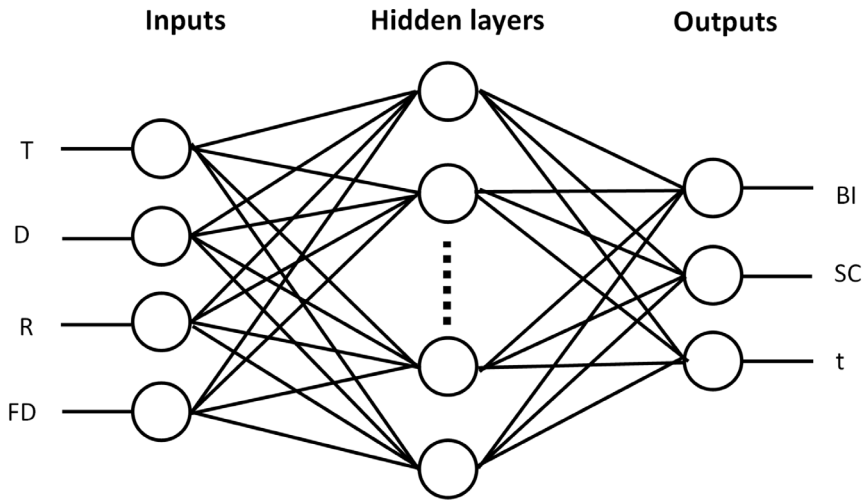

Figure 2. The typical diagram of developed ANN: T — storage temperature; D — fruit dimension; R — red value; FD — FD value; BI — browning index; SC — shrinkage coefficient; and t — shelf-life.

2.3.1 ANN performance

The selection of the best ANN for predicting quality and shelf-life of pineapple was based on their coefficient of determination (R^2) and mean square error (MSE) values. The best model should provide a highest R^2 and lowest MSE.

3. RESULTS AND DISCUSSION

3.1 Color

The significant change of redness (a^*) was found in fresh-cut pineapple stored at 10°C. The increased of a^* value regarding to the occurance of browning reaction during storage. Moreover, the lightness (L^*) of fresh-cut pineapple stored at 10°C was also gradually decreased as browning increased. In terms of lower storage temperature, all color parameters seemed to be constant with no significant change (Figure 3A-C). The results of browning index (BI) over storage time is shown in Figure 3D. The BI of 10°C stored pineapple showed the higher trend compared with those of 5°C.

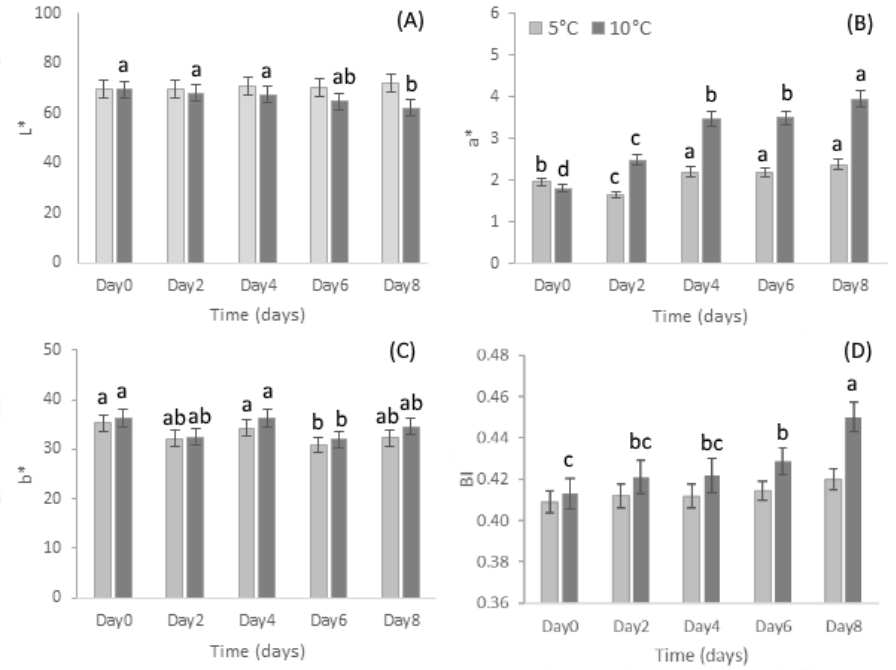

Figure 3. Effect of storage time and temperature on the change of fresh-cut pineapple color during storage: (A) — lightness; (B) — redness; (C) — yellowness; (D) — browning index.

3.2 Shrinkage

The results showed that the shrinkage coefficient of fresh-cut pineapple increased in all storage condition during storage (Figure 4A). At day 6, fresh-cut pineapple stored at 10°C had a significant higher shrinkage value compared with those of 5°C. Since water losses resulted to the change of cell structure. The internal structure collapsed led to the surface wilting and external structure shrinkage. A higher rate of shrinkage in fresh-cut fruit are also reported by a higher rate of water losses (Paniagua, East, Hindmarsh, & Heyes, 2013).

3.3 Firmness

The firmness of fresh-cut pineapple decreased after day 2 of storage in both storage conditions and remained constant (Figure 4B). At 5°C, the firmness seemed to be higher, but did not significant difference. Water losses might result in the change of fruit shrinkage, however, the fibrous surface of pineapple that exposed to the cold air seemed to dry and performed like a hard crust the firmness of fresh-cut pineapple was then remained constant during time of storage (Gallotta, Allegra, Inglese, & Sortino, 2018; Tirkey et al., 2014).

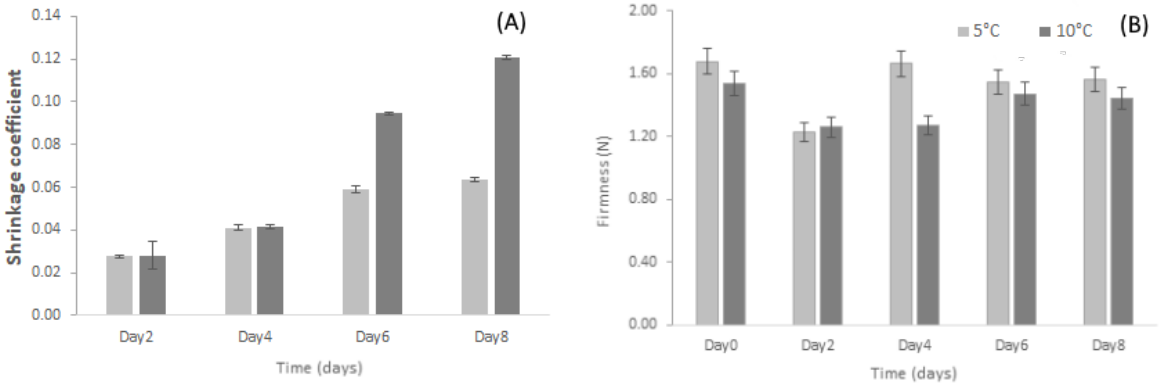

Figure 4. Effect of storage time and temperature on the shrinkage coefficient (A) and (B) firmness of fresh-cut pineapple.

3.4 Color

The results showed that the red (R) values significantly increased with the storage time, while the green (G) and blue (B) values were constant. The increased of browning on fresh-cut pineapple surface resulted in the increasing of R value. The increased of R value during storage was similar to the increased of *a** value (Cáez Ramírez et al., 2017; Nadafzadeh, Abdanan Mehdizadeh, & Soltanikazemi, 2018; Sanaeifar et al., 2016). Storage temperature was also had an influence on the change of R value. A greater increased of R value was found at storage temperature of 10°C. The converted CIELAB values showed a good agreement with those of actual value from colorimeter (Figure 5). The linear regressions showed a good fit between the converted and actual CIELAB values (R^2 >0.93). Moreover, the total color difference (ΔE) of this study was 3.54. The lower ΔE values showed the accuracy of the developed image analysis procedure (León et al., 2006).

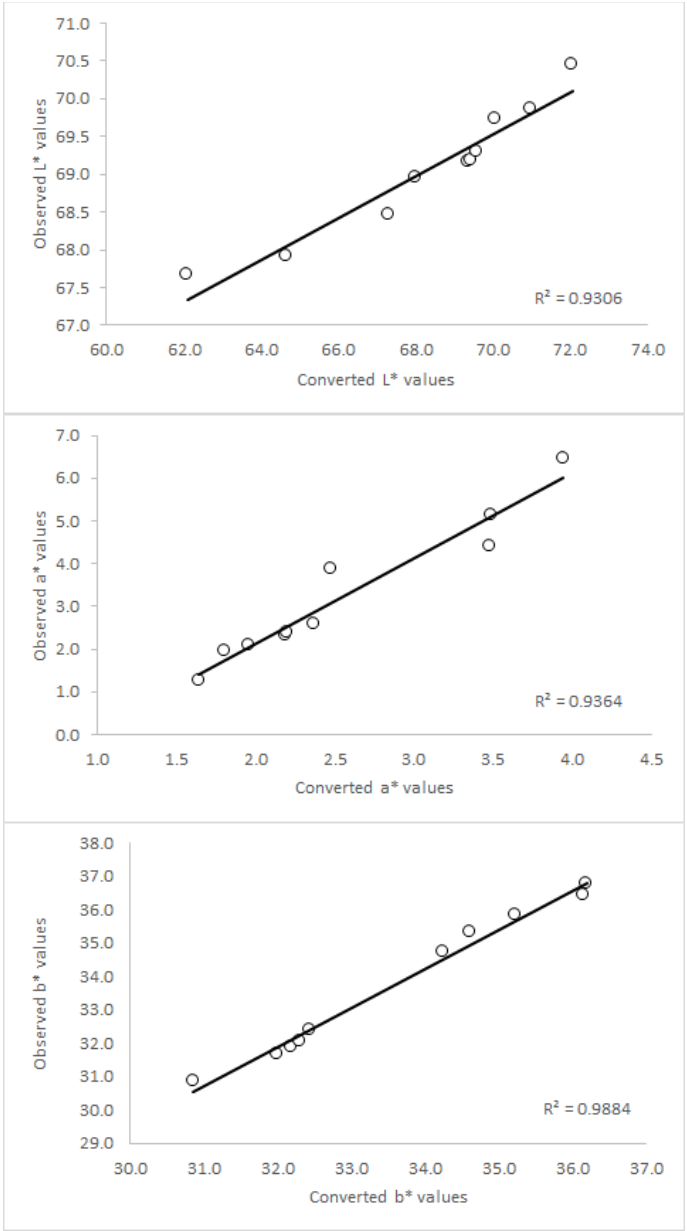

Figure 5. Comparison between converted and actual CIELAB values.

The correlation coefficients between the extracted RGB values, actual CIELAB of fresh-cut pineapple were investigated. Table 1 shows the significant correlation coefficient of RGB values with CIELAB values. According to the results, it indicated that R value was the best parameter for evaluating browning of fresh-cut pineapple.

Table 1. Peason's correlation coefficients between RGB values and CIELAB values.

Parameters	R	G	B	*L**	*a**	*b**
R	1.000					
G	0.577*	1.000				
B	0.328	0.468	1.000			
*L**	-0.921**	0.744**	0.696*	1.000		
*a**	0.934**	0.788**	0.639*	-0.800**	1.000	
*b**	-0.805**	0.738**	0.703**	0.533*	0.614*	1.000

**, * Denotes significant correlation coefficients at (P<0.01) and (P<0.05) by Peason's correlation test.

3.5 Dimension

The dimension reduction during storage was significant detected by image analysis. Table 2 shows the results of area and dimension reduction of fresh-cut pineapple during storage at 5 and 10°C. Both surface area and dimension were significantly reduced during storage. This may occur because of loss of water. Higher storage temperature caused fast shrinkage of fruit (Mahajan, Oliveira, & Macedo, 2008; Murmu & Mishra, 2016). The dimension reduction trend that observed from image analysis had a good agreement with those of shrinkage coefficient value.

Table 2. Effect of storage time and temperature on the change of fresh-cut pineapple's surface area and dimension.

Temperature	Time	Dimension reduction	Surface area reduction
°C	Day(s)	%	%
5	0	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}
	2	1.54 ± 0.17^{d}	3.06 ± 0.37^{d}
	4	2.61 ± 0.20^{c}	5.15 ± 0.21^{c}
	6	3.79 ± 0.29^{b}	7.44 ± 0.36^{b}
	8	4.15 ± 0.14^{a}	8.14 ± 0.22^{a}
10	0	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}
	2	2.38 ± 0.38^{c}	4.70 ± 0.66^{d}
	4	3.42 ± 0.23^{b}	6.72 ± 0.54^{c}
	6	4.32 ± 0.23^{a}	8.45 ± 0.24^{b}
	8	4.78 ± 0.28^{a}	9.33 ± 0.48^{a}

3.6 Fractal dimension

The results showed that fractal dimension values (FD) decreased during storage at 5°C. On the other hand, higher storage temperature of 10°C, the FD values found to be significantly increased (Table 3).

Table 3. Effect of storage time and temperature on the change of fractal dimension (FD) of fresh-cut pineapple.

Time	Temperature	
Day(s)	5°C	10°C
0	1.73 ± 0.02^{a}	1.67 ± 0.01^{c}
2	1.70 ± 0.07^{a}	1.67 ± 0.03^{c}
4	1.69 ± 0.02^{ab}	1.75 ± 0.01^{b}
6	1.68 ± 0.02^{ab}	1.77 ± 0.03^{b}
8	1.67 ± 0.04^{b}	1.83 ± 0.02^{a}

The decreasing of FD value was reported in fresh-cut fruit during storage since the uniform color distribution on fruit surface. Figure 7A-7E shows the RGB image of fresh-cut pineapple, uniformly change of surface color resulted in constant FD value after day 2 (1.67-1.70). The heterogeneous distribution of the color surface resulted in the increasing of FD value (R. Quevedo et al., 2016; Roberto Quevedo et al., 2009). The ununiform browning reaction on pineapple surface at 10°C might influenced the increasing of FD value (Figure 7K-7O).

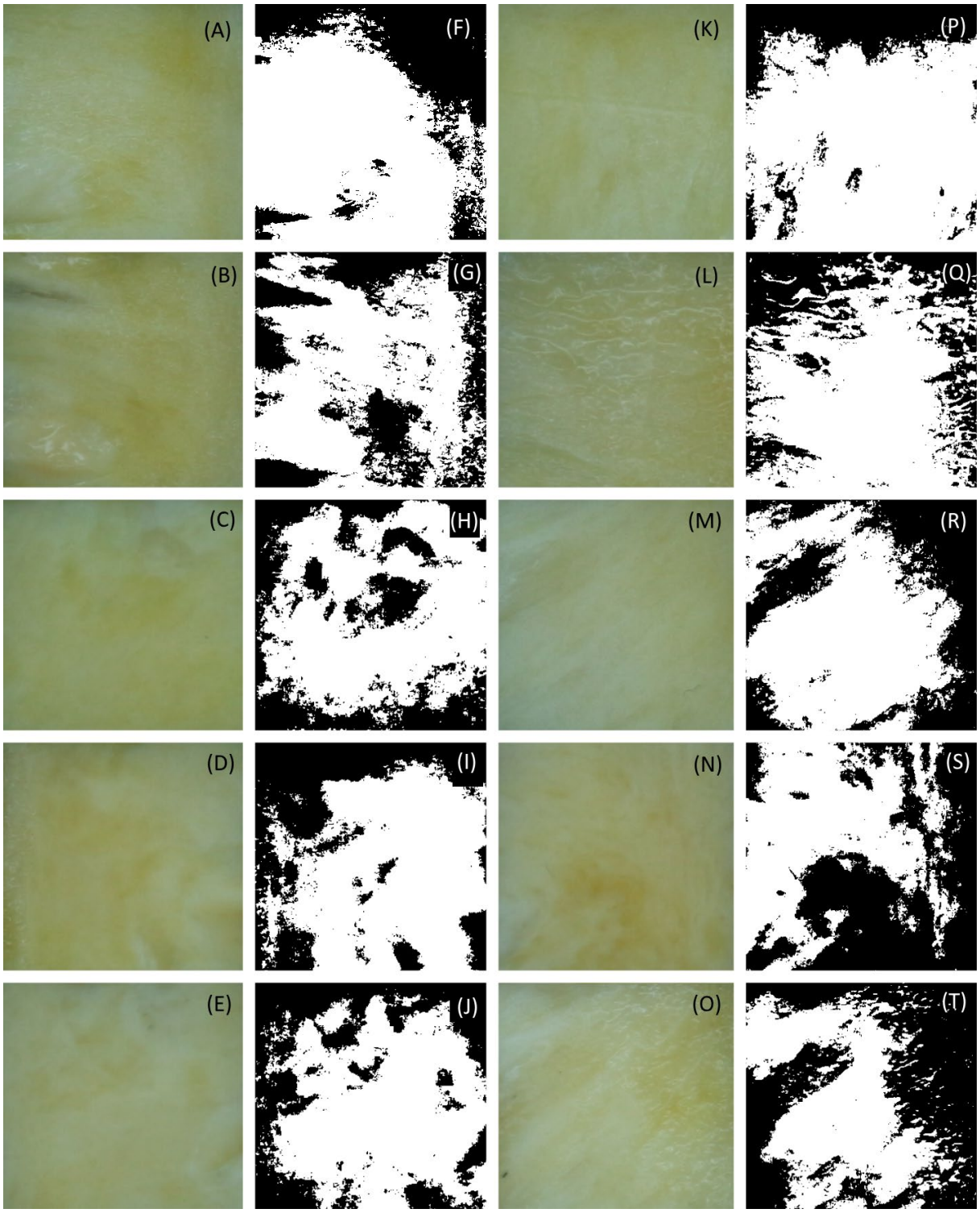

Figure 7. RGB images of fresh-cut pineapple stored at 5°C (A – day 0; B – day 2; C – day 4; D – day 6; and E – day 8) and 10°C (K – day 0; L – day 2; M – day 4; N – day 6; and O – day 8) and their corresponding binary image (5°C — F-J; 10°C — P-T) during storage.

3.7 ANN for qualities and shelf-life prediction

The performance of developed ANN shows in Table 4. The results showed that the 18-hidden node architecture provided the best prediction result with R^2 of 0.98 and MSE of 0.01, 0.002 and 0.2 day for browning index (BI), shrinkage coefficient (SC), and shelf-life (t), respectively. The results also showed that the increasing in number of the hidden node resulted in decreasing of prediction accuracy. A larger

number of hidden nodes increased the complexity of model architecture which lead to the increasing in prediction error (Mohi Alden et al., 2019; Shabani, Ghaffary, Sepaskhah, & Kamgar-Haghighi, 2017; Suárez Salazar, Melgarejo, Durán Bautista, Di Rienzo, & Casanoves, 2018). The accuracy of the developed model might decrease when the number of hidden node exceeded the optimum number.

Table 4. Prediction performance of developed ANN for predicting fresh-cut pineapple qualities and shelf-life.

Number of hidden node	R^2	Mean square error (MSE)		
		BI	SC	t (days)
2	0.88	0.05	0.010	1.0
4	0.86	0.05	0.010	1.0
6	0.89	0.05	0.009	0.9
8	0.91	0.03	0.006	0.6
10	0.93	0.02	0.004	0.4
12	0.94	0.02	0.004	0.4
14	0.92	0.02	0.003	0.3
16	0.95	0.02	0.003	0.3
18	0.98	0.01	0.002	0.2
20	0.95	0.02	0.003	0.3
22	0.96	0.02	0.003	0.3
24	0.93	0.02	0.004	0.4
26	0.93	0.02	0.004	0.4
28	0.92	0.02	0.003	0.3
30	0.92	0.02	0.003	0.3
32	0.91	0.04	0.008	0.8
34	0.88	0.05	0.009	0.9
36	0.88	0.05	0.010	1.0
38	0.86	0.06	0.011	1.1
40	0.88	0.06	0.011	1.1

4. CONCLUSION

The change of physical properties of fresh-cut 'Phulae' pineapple during cold storage was observed using both conventional and developed image analysis techniques. Higher storage temperature affected a higher change of all physical properties including color, shrinkage, firmness. The developed image analysis technique showed the possibility to determine the quality of fresh-cut as expected. The R and FD values were able to explain the occurrence of browning reaction occurred during storage. The dimension reduction obtained from image analysis could explain the change of product shrinkage with good agreement. The developed 18-hidden node ANN model with the selected inputs form image analysis including storage temperature, fruit dimension, R and FD values was able to estimate shelf-life, shrinkage and browning index of fresh-cut pineapple with a high accuracy ($R^2 > 0.98$).

ACKNOWLEDGMENT

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Oral Session | Postharvest/Food Technology and Process Engineering
[4-1600-C] Postharvest/Food Technology and Process Engineering (4)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room C (3rd room)

[4-1600-C-05] Stationary Machine Vision Based Real-Time Estimation of Japanese Black Cattle Serum Vitamin A using Eye Fundus Color

*SAMUEL OUMA OTIENO[1], Naoshi Kondo[1], Tateshi Fujiura[1], Yuichi Ogawa[1], Tetsuhito Suzuki[1], Katsuya Takenouchi[1], Hidetsugu Yoshioka[1], Moriyuki Fukushima[2], Takahiko Ohmae[3] （1. Graduate School of Agriculture, Kyoto University(Japan), 2. Hyogo Prefectural Hokubu Agricultural Institute(Japan), 3. Tajima Agricultural High school(Japan)）

Keywords: Japanese Black Cattle, Beef, Vitamin A, Fundus Color, Machine Vision

Japanese black cattle are well known all over the world for their highly tender and deep flavored beef. In Japan, Beef Marbling Standards (BMS) has predominantly become the most influential factor for deciding the beef quality. Due to the negative correlation between serum vitamin A (Vit. A) level and BMS, higher BMS has been achieved by gradually reducing the amount of serum Vit. A in the cattle during fattening. This activity can be dangerous therefore needs to be precisely monitored. The conventional way of monitoring Vit. A level is by blood sampling and it`s very costly, time-consuming, and stressful to the cattle. As a result, our laboratory members have tirelessly conducted a number of researches to develop the best alternative. These previous researches have achieved Vit. A level estimation from the eye surface features like pupil color, pupil reflection, and pupil light reflex. In this research, we investigate the eye fundus color in addition to the pupil color, pupil reflection, and pupil light reflex in a stationary machine vision system to estimate serum Vit. A level in Japanese Black Cattle.

Stationary Machine Vision Based Real Time Estimation of Japanese Black Cattle Serum Vitamin A using Eye Fundus Color

°Samuel Ouma[1], Naoshi Kondo[1], Tateshi Fujiura[1], Yuichi Ogawa[1], Tetsuhito Suzuki[1], Katsuya Takenouchi[1], Hidetsugu Yoshioka[1], Moriyuki Fukushima[2], Takahiko Ohmae[3]

[1]Graduate School of Agriculture, Kyoto University
[2]Hyogo Prefectural Hokubu Agricultural Institute
[3]Tajima Agricultural High school

[Introduction]

Japanese black cattle are well known for their highly tender and deep flavored beef. To meet consumers demand, the Japanese farmers consistently add value by producing high quality beef. The degree of marbling (BMS) has predominantly become the most influential factor for deciding the quality. This is because of the slight increase in flavor, juiciness, and tenderness associated with.

Due to the negative correlation between serum vitamin A (vit. A) level and BMS, higher BMS have been achieved by gradually reducing the amount of serum vit. A in the cattle during fattening [2)]. However, vit. A level lower than 30IU/dL is dangerous to cattle health [1)]. Hence, the need to monitor vit. A level during fattening.

The convectional way of monitoring vit. A level is by blood sampling which is very costly, invasive, time consuming, and stressful to the cattle. As a result, our laboratory members have over the years conducted a number of researches to develop the best alternative. These researches have achieved vit. A level estimation from the eye surface features which includes pupil color, pupil reflection, and pupil light reflex.

However, these methods rely to a large degree average reflection from the pupil when an incident light interacts with the inside of the eye. Because of diffused reflection inside the eye, the image of the pupil area is usually not clear.

To improve the image quality, a fundus image (inner lining of the eye) and additional color feature of the fundus were acquired for vit. A level estimation. Another advantage of adding fundus color changes are that they are a consistent sign compared to other ocular changes[2)]. These changes reflect the general systemic level of vit. A.

[Experimental Method

Four Japanese Black cattle raised in Tajima Agricultural High School; Hyogo Prefecture from May 2017 until June 2019 were used. The vit. A level measured by blood assay in these cattle ranged from 14 to 98 IU/dL. An automatic image acquisition system was developed and installed at the cattle drinking place. When system detects the cattle drinking, cattle's eye is illuminated by white LED and the tapetum image is captured.

The fundus area was automatically extracted from the original image using C++ program and OpenCV library (Fig. 1). Fundus color feature was analyzed and the relationship between vit. A with *r*, *g*, and *b* component ratios were investigated.

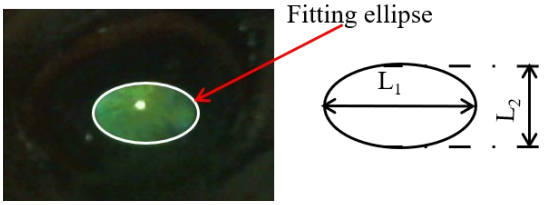

Fig. 1 Image of the fundus and the fitting ellipse

The Red (*r*), Blue (*b*), and Green (*g*) component ratios were calculated by the formulas:

$r=R/(R+G+B)$, $b=B/(R+G+B)$, $g=G/(R+G+B)$

[Results and Discussion]

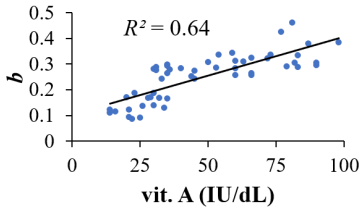

Fig. 2 Relationship of and *b* ratios with vit. A level

The *b* component (Fig. 2) values had a clear positive correlation (R^2 = 0.64) with vit. A level changes. While on the other hand, the *r* component values showed a negative correlation (R^2 = 0.58) with vit. A. Cattle eye fundus is typically tapetal. Under normal circumstances of vit. A, the tapetum in cattle appears greenish-blue in color[3)]. Under vit. A deficiency, the tapetum became bleached.

[References]

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*E-mail: oumasamuel17@gmail.com

5:15 PM - 5:30 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room C)

[4-1600-C-06] Segmentation of common scab lesion on intact potatoes using single near-infrared image

*Dimas Firmanda Al Riza[1,2], Kazuya Yamamoto[3], Kazunori Ninomiya[3], Tetsuhito Suzuki[1], Yuichi Ogawa[1], Naoshi Kondo[1] （1. Laboratory of Biosensing Engineering, Graduate School of Agriculture, Kyoto University, Kitashirakawa 6068267, Kyoto(Japan), 2. Department of Agricultural Engineering, Faculty of Agricultural Technology, University of Brawijaya, Jl. Veteran 65145, Malang(Indonesia), 3. Product Planning Department, Shibuya Seiki Co., Ltd. 2200, Minamiyoshida, Matsuyama, Ehime, 791-8042(Japan)）
Keywords: image processing, common scab, external defects , near infrared, segmentation

Segmentation and identification of potato common scab lesion on a single near infrared image is the objective of this research. A more simple machine vision system is desired for sorting system application. Thus, a minimum number of the image is preferable compared to multispectral images for speediness if it can give good results. In this research, we proposed an imaging system using an InGaAs camera and a bandpass filter at 1600 nm which found to provide a good contrast of common scab lesion to normal potato skin. An image correction method was employed to deal with uneven light distribution due to the various shape of potatoes. Image segmentation has been successfully carried out with a Dice Sorensen coefficient of 0.72. Results also show that external defects, such as common scab and some mechanical damage types, and soil deposits appear brighter in the near infrared region, against the normal skin background. Thus, further image analysis of area shape and textural features has been provided to discriminate common scab and other classes. The results could be used as consideration for a real sorting application.

5:30 PM - 5:45 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room C)

[4-1600-C-07] Myanmar Mango Maturity Prediction Based on Skin Color Using Machine Vision System

*RULIN CHEN[1], Dimas Firmanda Al Riza[1], Thwe Thwe Tun Naw[2], Phyu Phyu Leiyi[2], Aye Aye Thwe[2], Khin Thida Myint[1], Yuichi Ogawa[1], Tetsuhito Suzuki[1], Naoshi Kondo[1] （1. Kyoto University(Japan), 2. Yezin Agricultural University(Myanmar)）
Keywords: Maturity prediction, Machine vision

Mango fruits mostly in Myanmar, are harvested without maturity grading, which will cause later problems in processing and transportation. Mangoes of different maturity level show difference in skin characteristics like color. As machine vision system can acquire visual information of an object and give feedback in a short time, it is likely to be an effective method to predict mangoes’ maturity based on their skin characteristics. In this study, to better evaluate mangoes’ skin characteristics, 3 color models (RGB, HSV, CIELAB) were compared and discussed. Sein ta Lone mangoes' skin characteristics during maturation were recorded as color images and fluorescence images using USB camera with white and UV LED illumination. Changes of color figures in 3 color models of 2 types of images during maturation were analyzed using Mat lab and compared. As a result, a* value from the CIELAB color model is observed an obvious change during mango maturation in color images compared to others.

Oral Session | Postharvest/Food Technology and Process Engineering
[4-1600-C] Postharvest/Food Technology and Process Engineering (4)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room C (3rd room)

[4-1600-C-08] Measurement of Chicken Eggshell Optical Properties Using Terahertz Spectroscopy

*Alin Khaliduzzaman[1,3], Keiji Konagaya[1], Tetsuhito Suzuki[1], Ayuko Kashimori[2], Naoshi Kondo[1], Yuichi Ogawa[1]
（1. Graduate School of Agriculture, Kyoto University(Japan), 2. NABEL Co., LTd.(Japan), 3. Department of Food Engineering and Technology, Sylhet Agricultural University(Bangladesh)）

Keywords: Eggshell, Optical properties, Refractive index, Dielectric constant, Extinction co-efficient, Terahertz spectroscopy

Terahertz (THz) is a relatively new and under explored part of the electromagnetic spectrum that promises to be an extremely useful tool for research in the agricultural sciences. One such under explored area is how it interacts with biological objects like avian eggs. In this respect, chicken eggs are considered an ideal representative for avian studies. Eggshell plays various important roles such as protecting the internal contents and embryo of these eggs from ultraviolet (UV) rays, predators and contaminants. In addition, it provides major minerals for embryo development and facilitates embryonic respiration (i.e. gas exchange) during incubation. Electromagnetic waves below the THz range are limited in their ability to probe eggshell properties due to high absorbance and scattering effects in the UV, Visible and even NIR regions. Moreover, eggshell color pigment, called protoporphyrin, masks measurements in the Visible region. Therefore, we aim to measure the optical properties of the chicken eggshell using THz waves to obtain foundational data for researchers working on avian and reptile eggs. Moreover, this dataset could help to inform scientists regarding eggshell factors relevant to their research protocols. Optical properties of chicken (layer) eggshell, such as refractive index, dielectric constant and extinction co-efficient, were measured using Terahertz Time domain Spectroscopy (0.2 to 3.0 Terahertz). THz transmission and THz reflection were measured for broken eggshell and intact eggshell respectively. The refractive index of the eggshell increased slightly with increasing THz frequency; varying from 2.7 to 3.3. Whereas the extinction co-efficient sharply increased from 0.2 to 2.0 THz. The dielectric constant of the eggshell increased slightly from 7.0 to 10.2 in the 0.2 to 2.0 THz range. This research has shown that when probing the optical properties of crystalline structures with very low water content, such as eggshells, THz waves are an appropriate tool. The foundational properties documented in this research can be used in various applied research fields (e.g. applied optics, ecology, ornithology, evolutionary biology) in the future.

Measurement of Chicken Eggshell Optical Properties Using Terahertz Spectroscopy

Alin Khaliduzzaman[1,3*], Keiji Konagaya[1], Tetsuhito Suzuki[1], Ayuko Kashimori[2], Naoshi Kondo[1], Yuichi Ogawa[1]

[1]Graduate School of Agriculture, Kyoto University, [2]NABEL Co., Ltd., Japan,

[3]Department of Food Engineering and Technology, Sylhet Agricultural University, Bangladesh

*E-mail: khaliduzzaman.88s@st.kyoto-u.ac.jp

Terahertz (THz) is a relatively new and under explored part of the electromagnetic spectrum that promises to be an extremely useful tool for research in the agricultural sciences. One such under explored area is how it interacts with biological objects like avian eggs. In this respect, chicken eggs are considered an ideal representative for avian studies. Eggshell plays various important roles such as protecting the internal contents and embryo of these eggs from ultraviolet (UV) rays, predators and contaminants. In addition, it provides major minerals for embryo development and facilitates embryonic respiration (i.e. gas exchange) during incubation. Electromagnetic waves below the THz range are limited in their ability to probe eggshell properties due to high absorbance and scattering effects in the UV, Visible and even NIR regions. Moreover, eggshell color pigment, called protoporphyrin, masks measurements in the Visible region. Therefore, we aim to measure the optical properties of the chicken eggshell using THz waves to obtain foundational data for researchers working on avian and reptile eggs. Moreover, this dataset could help to inform scientists regarding eggshell factors relevant to their research protocols. Optical properties of chicken (layer) eggshell, such as refractive index, dielectric constant and extinction co-efficient, were measured using Terahertz Time domain Spectroscopy (0.2 to 3.0 Terahertz). THz transmission and THz reflection were measured for broken eggshell and intact eggshell respectively. The refractive index of the eggshell increased slightly with increasing THz frequency; varying from 2.7 to 3.3. Whereas the extinction co-efficient sharply increased from 0.2 to 2.0 THz. The dielectric constant of the eggshell increased slightly from 7.0 to 10.2 in the 0.2 to 2.0 THz range. This research has shown that when probing the optical properties of crystalline structures with very low water content, such as eggshells, THz waves are an appropriate tool. The foundational properties documented in this research can be used in various applied research fields (e.g. applied optics, ecology, ornithology, evolutionary biology) in the future.

Keywords: Eggshell, Optical properties, Refractive index, Dielectric constant, Extinction co-efficient, Terahertz Spectroscopy

6:00 PM - 6:15 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room C)

[4-1600-C-09] Application of LCA (Life Cycle Assessment) Methodology in Bioethanol Production from Sugar Industry Wastewater (Molasses) – A Case Study in West Java Province, Indonesia

*Agusta Samodra Putra[1,2], Ryozo Noguchi[3], Tofael Ahamed[3] （1. Graduate School of Life and Environmental Sciences, University of Tsukuba(Japan), 2. Research Center for Chemistry, Indonesian Institute of Sciences(Indonesia), 3. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan)）
Keywords: molasses, LCA, sugar industry, bioethanol

Sugar industry plays an important role in Indonesia. Sugar industry wastes consist of biomass waste (sugarcane bagasse) and liquid waste (molasses). To increase the economic and environmental performance in the sugar industry, utilization of molasses for biorefinery product such as bioethanol is the appropriate solution. In this study, the environmental performance of integrated sugar and bioethanol industry in West Java Province was investigated. Life Cycle Inventory of sugar industry in Subang and bioethanol industry in Palimanan, West Java Province, Indonesia was investigated. This LCA study follows a *gate-to-gate* system boundary from the sugar industry to bioethanol production. SimaPro v8.0.5 software was used for LCA calculation with Chain Management by Life Cycle Assessment (CML) as an environmental impact assessment method. Acidification potential (AP), global warming potential (GWP100), eutrophication potential (EP), and human toxicity potential (HTP) were quantified with 1 kg of bioethanol product as a functional unit. Based on LCA approach, environmental impacts for producing 1 kg of bioethanol from molasses are 0.0030 kg SO_2 eq of AP, 0.1929 kg CO_2 eq of GWP100, 0.0004 kg PO_4 eq of EP, and 0.1494 kg 1,4-DB eq of HTP. Utilization of chemicals in the fermentation process gave a significant environmental impact. Sugarcane bagasse waste in this industry was used for heat and power generation that enough to fulfill process energy requirement. Environmental performance improvement can be proposed by using the LCA approach. In this industry, chemical usage in the fermentation process is the main environmental impact contributor.

Oral Session | Others (including the category of JSAM and SASJ)

[4-1600-D] Other Categories (1)

Chair:Satoshi Yamamoto(Akita Prefectural University), Kikuhito Kawasue(University of Miyazaki)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room D (4th room)

[4-1600-D-01] Applicability Of Japanese Standard About The Powered Exoskeleton To Agriculture

*Masahiro Tanaka[1], Satoru Umeno[1], Yutaka Kikuchi[1] (1. National Agriculture and Food Research Organization(Japan))

4:00 PM - 4:15 PM

[4-1600-D-02] Research on an Intelligent Robot Eye-hand System for Harvesting Pumpkin in the Outdoor Condition

*Liangliang Yang[1], Qian Wang[2], Yohei Hosino[1], Hiroki Ishikuro[1], Ying Cao[1] (1. Kitami Institute of Technology(Japan), 2. Ning Xia University(China))

4:15 PM - 4:30 PM

[4-1600-D-03] Handy Type Pig Weight Estimation System Based on Random Forest Algorithm

*Hsu Lai Wai[1], Kikuhito Kawasue[1], Khin Dagon Win[1], Kumiko Yoshida[2] (1. University of Miyazaki(Japan), 2. KOYO Plant Service(Japan))

4:30 PM - 4:45 PM

[4-1600-D-04] Plant Disease Identification using Explainable Features with Deep Convolutional Neural Network

*Harshana Habaragamuwa[1], Yu Oishi[1], Katu Takeya[1], Kenichi Tanaka[1] (1. National Agriculture and Food Research Organization(Japan))

4:45 PM - 5:00 PM

[4-1600-D-05] Sensitivity and Dynamic Analysis of Microalgae Fuel Production System Using LCA

*Riaru ISHIZAKI[1], Ryozo Noguchi[2], Agusta Samodra Putra[1], Tofael Ahamed[2], Makoto M. Watanabe[3] (1. Graduate School of Life and Environmental Sciences, University of Tsukuba(Japan), 2. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan), 3. Algae Biomass and Energy System R&D Center, University of Tsukuba(Japan))

5:00 PM - 5:15 PM

[4-1600-D-06] An Aerial Weed Detection System for Green Onion Crops Using the You-Only-Look-Once (YOLO) Deep Learning Algorithm

Addie Ira Borja Parico[1], *Tofael Ahamed[2] (1. College of Agrobiological Resource Sciences, School of Life and Environmental Sciences, University of Tsukuba(Japan), 2. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan))

5:15 PM - 5:30 PM

[4-1600-D-07] A Deep Learning and MSM Machine Learning System for Recognition of Weed Infestation in Cabbage Field Using Unmanned Aerial Vehicle

*Tofael Ahamed[1], Yan Zhang[1], Linhuan Zhang[1], Ryozo Noguchi[1] (1. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan))

5:30 PM - 5:45 PM

[4-1600-D-08] **Mallard Navigation Using Unmanned Ground Vehicles, Imprinting, and Feeding**

*Hirokazu Madokoro[1], Satoshi Yamamoto[1], Hanwool Woo[1], Kazuhito Sato[1] （1. Akita Prefectural University(Japan)）

5:45 PM - 6:00 PM

[4-1600-D-09] **Onion Bulb Counting in a Large-scale Field Using a Drone with RTK-GNSS**

*Satoshi Yamamoto[1], Hirokazu Madokoro[1], Yo Nishimura[1], Yukio Yaji[1] （1. Akita Prefectural University(Japan)）

6:00 PM - 6:15 PM

Oral Session | Others (including the category of JSAM and SASJ)
[4-1600-D] Other Categories (1)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room D (4th room)

[4-1600-D-01] Applicability Of Japanese Standard About The Powered Exoskeleton To Agriculture

*Masahiro Tanaka[1], Satoru Umeno[1], Yutaka Kikuchi[1] (1. National Agriculture and Food Research Organization(Japan))

Keywords: Powered Exoskeleton, Labor-Saving technology, Assistive technology, ISO 13482, JIS B8456-1

In japan, various types of powered exoskeletons have been developed for long ago such as military, construction, transportation, manufacturing and agriculture and now some of them are in the market. They are expected to reduce a physical load on workers resulting from picking up heavy object or continuous working in a half-sitting posture for long time and free workers from these heavy labors because aging labor population has become a serious problem and elderly people and women have need to perform the heavy labors in Japan. For this reason, the robots coexisting with human that provide services to people and used in same space with human have been developed so far and now it is called service robot, which performs useful task for human and equipment excluding industrial automation applications. Furthermore, Japan proposed safety requirements for personal care robots that is a kind of service robots including powered exoskeleton to ISO and it was published as ISO 13482 on 2014. In this way, Japan is not only paying attention to developing but also establishment of standards about service robots. Especially regarding a powered exoskeleton for lumbar support, a Japanese national standard that specified safety and performance requirements was published as JIS B8456-1 developed from ISO 13482 on 2017. However, it needs to consider details in each field to widely spread through the market, because JIS B8456-1 was cross-cutting standard that summarized the minimum and common requirements in various fields. Therefore, we examined the applicability of this standard to agriculture and there were some problems as a result. Regarding safety requirements, it was considered necessary to identify particular risk factors of using a powered exoskeleton that have the potential to cause harm when farmer would use it in their farm work. Therefore, the authors summarized the risk assessment sheet about using a powered exoskeleton in farm work, so that estimated that unstable surfaces of ground might cause user falling down in particular. Regarding performance requirements, the test methods that measuring assistive torque a powered exoskeleton have were not suitable for agricultural use because it was only for static force however not for dynamic force. Accordingly, the authors developed a measuring instrument and test method for measuring the dynamic assistive torque in consideration of agricultural use. Furthermore, they examined the plasticity using a powered exoskeleton for farm work made in Japan. As a result, the dynamic assistive torque properties were revealed with high reproducibility and standard deviation of maximum and average assistive torque were lower than 1 N・m. the authors expect that risk assessment sheet and measuring instrument they developed can improve applicability of Japanese standard about the powered exoskeleton to agriculture.

Applicability Of Japanese Standard About The Powered Exoskeleton To Agriculture

Masahiro Tanaka*, Yutaka Kikuchi, Satoru Umeno

Institute of Agricultural Machinery, National Agriculture and Food Research Organization, Japan

*Corresponding author: email address tanakam183@affrc.go.jp

ABSTRACT

In Japan, various types of powered exoskeletons have been developed for long ago such as military, construction, transportation, manufacturing and agriculture and now some of them are in the market. They are expected to reduce a physical load on workers resulting from picking up heavy object or continuous working in a half-sitting posture for long time and free workers from these heavy labors because aging labor population has become a serious problem and elderly people and women have need to perform the heavy labors in Japan. For this reason, the robots coexisting with human that provide services to people and used in same space with human have been developed so far and now it is called service robot, which performs useful task for human and equipment excluding industrial automation applications. Furthermore, Japan proposed safety requirements for personal care robots that is a kind of service robots including powered exoskeleton to ISO and it was published as ISO 13482 on 2014. In this way, Japan is not only paying attention to developing but also establishment of standards about service robots. Especially regarding a powered exoskeleton for lumbar support, a Japanese national standard that specified safety and performance requirements was published as JIS B8456-1 developed from ISO 13482 on 2017. However, it needs to consider details in each field to widely spread through the market, because JIS B8456-1 was cross-cutting standard that summarized the minimum and common requirements in various fields. Therefore, we examined the applicability of this standard to agriculture and there were some problems as a result. Regarding safety requirements, it was considered necessary to identify particular risk factors of using a powered exoskeleton that have the potential to cause harm when farmer would use it in their farm work. Therefore, the authors summarized the risk assessment sheet about using a powered exoskeleton in farm work, so that estimated that unstable surfaces of ground might cause user falling down in particular. Regarding performance requirements, the test methods that measuring assistive torque a powered exoskeleton have were not suitable for agricultural use because it was only for static force however not for dynamic force. Accordingly, the authors developed a measuring instrument and test method for measuring the dynamic assistive torque in consideration of agricultural use. Furthermore, they examined the plasticity using a powered exoskeleton for farm work made in Japan. As a result, the dynamic assistive torque properties were revealed with high reproducibility and standard deviation of maximum and average assistive torque were lower than 1 N・m. the authors expect that risk assessment sheet and measuring instrument they developed can improve applicability of Japanese standard about the powered exoskeleton to agriculture.

Keywords: Powered Exoskeleton, Labor-Saving technology, Assistive technology, ISO 13482, JIS B8456-1

1. INTRODUCTION

Japan is one of the robotic powers in the world and the value of shipments of robotics was approximately 900 billion in 2018(Japan Robot Association, 2019). Cabinet Office (2007) estimated that domestic market size of robotics would be 9.7 trillion by 2035 considering future spread of robotics into new fields such as service industry and growth of fields such as manufacturing industry that currently forms the market. Especially, tertiary sector of industry including service industry has been expected to be able to apply robotics in the near future and development of robots for these industries have been promoted.

These robots are called “service robot” and mean robot that performs useful tasks for people or device excluding the use of industrial automation (ISO 13482, 2014). Safety of service robot has been a

problem while expected as major driving force for jump in robot industry in Japan. Sugimoto (2005) mentioned that it was essential to ensure safety of service robot in world-class way to foster robot industry soundly because it might be a sensational event that other machines would not even if an accident rarely occurred. From such a thought, Japan has been considering standardization of safety for service robot since many years ago.

According to Yamada et al. (2007, 2009, 2013), the flow of standardization for service robot is as follows. First of all, discussion about safety for service robot at ISO started in 2002. Hungary proposed standardization activities as robotics application-safety for human rehabilitation within a framework of industrial manipulator at this time, but it was rejected as result of voting by reason that robot for rehabilitation could not be regarded as an application of industrial manipulator. Subsequently, AG (Advisory Group) and 16 WG for mobile servant robot was established in 2005 and the investigation and discussions about NWI (new work item) that should have been targeted as standardization of mobile servant robot been conducted for two years. As a result, PT (Project Team) was established because safety was essential as industries waiting for market expansion and targeted as international standardization that required urgent action. Formulation of standard had been advanced after establishment of WG7 at general meeting of TC 184/SC 2 in 2009 and ISO 13482 was published in 2014 after adopting in FDIS voting.

ISO 13482 regulated three personal care robots out of service robot that performed actions directly to improve the quality of life excluding personal care robot moving at a speed over 20km, underwater robot and flight robot, Industrial robot, robot as medical equipment, robot as military or public power. One of them was physical assistant robot performing assistant or reinforcement of personal physical ability. Requirements for intrinsic safety design, protective measure and information for use were regulated in this. Afterwards, Japanese Industrial Standard for safety requirements of these personal care robots was published as JIS B 8446 and that for safety and performance requirements of powered exoskeleton for lumbar support was published as JIS B 8456-1 in Japan.

JIS B 8456-1 was advanced standard for powered exoskeleton, however, on the other hand, minimum common standard with an eye to the future that new one would appear. Therefore, each industry or fields requires to consider an applicability of this standard to their territory. In this paper, the author considered the applicability of this standard to agriculture and what was necessary for that.

2. MATERIALS AND METHODS

JIS B 8456-1 was generally consist of performance test method and safety requirements for powered exoskeleton. Thus, we considered each applicability to agriculture in the following way.

2.1 Performance test method

JIS B 8456-1 regulated two performance test methods. The one was maximum assistive torque measurement method, the other was disc compression forces and lumbar spine torque measurement method using robot imitating human shape. We actually measured maximum assistive torque of one powered exoskeleton made in Japan following procedure regulated in JIS B 8456-1 that described static torque measurement method, shown Fig1. In summary, the measurer had force gauge and then pull a thigh segment of powered exoskeleton fastened to pedestal while that is working, like tug of war. Although this method was not bad, we confirmed the necessity of dynamic torque measurement to apply this standard to agriculture because body movement farm worker's doing is very fast. Actually, dynamic torque measurement method was considered in the drafting committee of this standard but not regulated because of difficulty and lack of repeatability in testing.

Therefore, we developed a simple and reliable measuring instrument and test method for measuring a dynamic assistive torque generated by the powered exoskeleton and tested functionality of them. Measuring instrument that we developed, shown Fig.2, composed to the fixed pedestal for fastening a powered exoskeleton, an electric slider and the wire with a load cell that connects the powered exoskeleton with the electric slider through a pulley. The powered exoskeleton is fastened to the pedestal shaped like a chair, which was built with a frame and fixed on the floor, by load binding belt. Metal plate substituted for a thigh segment of the powered exoskeleton is bolted to the wire connected to the electric slider, which can move up and down within the range of 500mm stroke, through the pulley. Besides, a load cell attached to the wire provides a pulling force on the wire pulled by metal plate equipped with the powered exoskeleton when it is in operation and metal plate is rotating according to the movement of the electric slider. we examined the repeatability using this instrument.

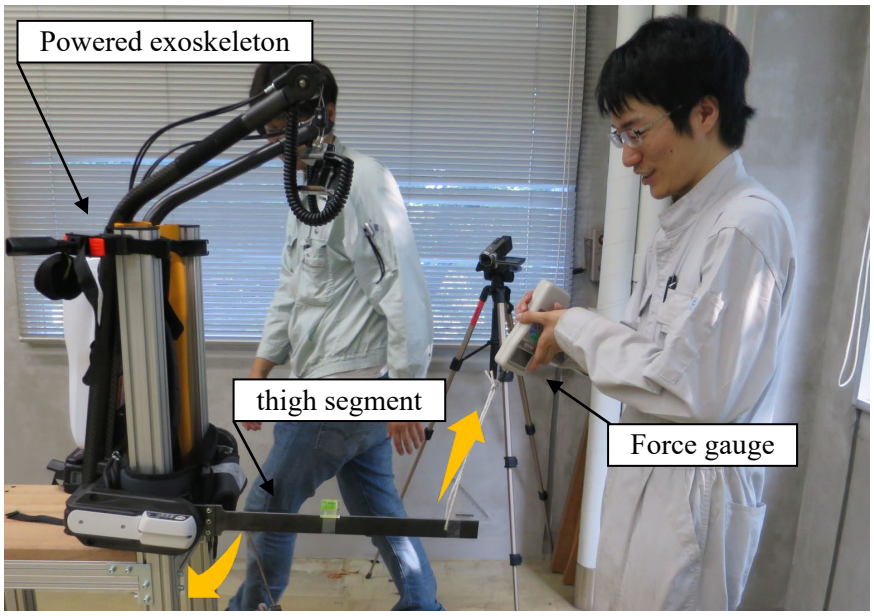

Figure 1. Performance test method regulated in JIS B8456-1.

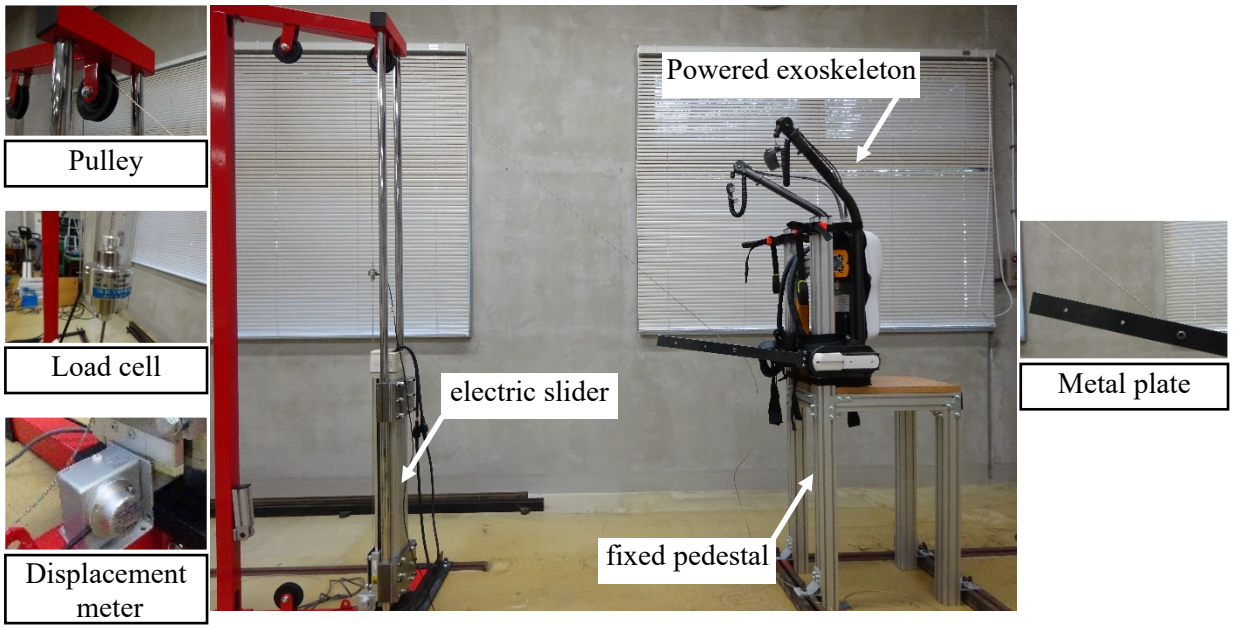

Figure 2. Appearance of the measuring instrument we developed

2.2 Safety requirements

We performed detailed check about safety requirements and related item that powered exoskeleton should have satisfy such as risk assessment, construction, shape, size and mass in JIS B 8456-1 while considering the situation where powered exoskeleton was used in agriculture. As a result, most of them were necessary even considering agricultural use and could be applied to agriculture as it was. For example, thought and value of requirements such as “upper limit of assistive torque should not exceed human power “, “powered exoskeleton should have back drivability under working or not working condition” and “protecting users from electric shock” were acceptable and applicable to any industry and field. However, only risk assessment needed to be performed anew in each industry and field that this standard would not assume at the beginning. Therefore, we performed extraction of typical risks expected in agricultural use of powered exoskeleton.

3. RESULTS AND DISCUSSION

The results of our consideration were as follows.

3.1 Performance test method

The result of testing was shown in Fig.3. The characteristics of dynamic assistive torque that the powered exoskeleton has was revealed with high repeatability such as Maximum torque and its duration, torque increasing gradient characteristics and decreasing gradient characteristics were different greatly each step. Maximum and average torque of the powered exoskeleton are following: left side is 44.0 N·m and 40.5 N·m, right side is 47.2 N·m and 41.0 N·m in step of 'high', and 5 times standard deviation of them are lower than 1 N·m.

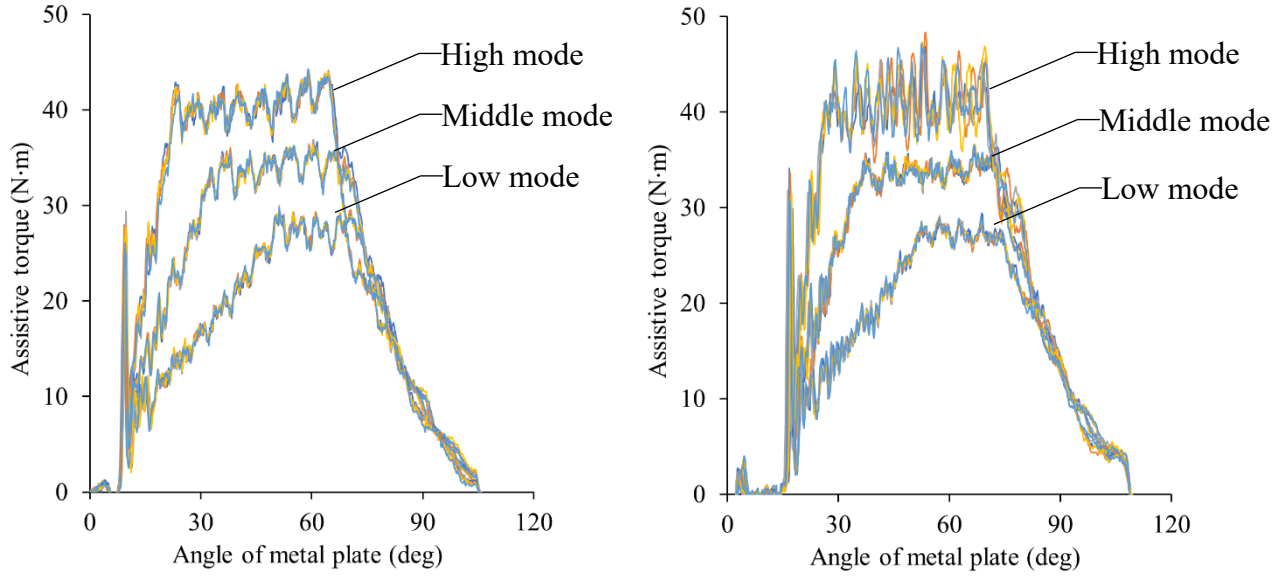

Figure 3. Appearance of the measuring instrument we developed

3.2 Safety requirements

A part of typical risks and the example expected in agricultural use was shown in Table 1. Falling due to unstable ground or slopes such as orchards and field as agricultural specific risks. We considered that detailed examination was necessary what process might lead to falling for user with powered exoskeleton.

Table 1. Typical risks expected in agricultural and the example.

Typical risks expected in agricultural use	Examples
Falling due to unstable ground or poor environment	Work on slopes such as orchards Work in a field with poor footing due to rain etc. Work in heavy rain and wind
Falling due to contact with an object	Contact to the branches of fruit trees in orchards Contact to branches and vines in vegetable cultivation
Obstruction of fall avoidance due to powered exoskeleton working	When use is taken suddenly in the field When use is taken on poor footing or slopes
User's mistake	Overweight User's poor health Lack of user's skill Wrong way to wear

4. CONCLUSION

We considered the applicability of this standard to agriculture and what was necessary for that. As a result, regarding to performance test method, we considered that could be apply to agriculture by using our measuring instrument measuring dynamic assistive torque important in farm work. Regarding safety requirements, risk assessment for agricultural use of powered exoskeleton and detailed examination was necessary such as what process might lead to falling for user with that.

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4:15 PM - 4:30 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room D)

[4-1600-D-02] Research on an Intelligent Robot Eye-hand System for Harvesting Pumpkin in the Outdoor Condition

*Liangliang Yang[1], Qian Wang[2], Yohei Hosino[1], Hiroki Ishikuro[1], Ying Cao[1] (1. Kitami Institute of Technology(Japan), 2. Ning Xia University(China))

Keywords: Robot, Machine vision, Harvester, Pumpkin

Hokkaido is the largest pumpkin planting region in Japan. However, the planting area is shrinking these years for the shortage of labor force for harvesting the pumpkin fruits. An autonomous robot harvesting system is required by farmers. In addition, the farmers asked us that the surface of the fruits cannot be scrubbed, because of the restrict market requirement of vegetables. Moreover, the storage span will be shorter if the surface has broken points. Therefore, a robot eye-hand system is going to be developed for harvesting the pumpkin fruit. There are three modules of the harvester robot, which are fruits detection module, position coordinates transform and communication module, and robot arm module. In the first module, a color USB camera (IDS, xs, Germany) was utilized to grab images of the field on the speed under 30 frame per second (FPS). The grabbed images were processing in real-time by using faster regional convolutional neural-network (faster R-CNN) method. The pumpkin fruits can be detected correctly around 90% using the method. The detected results were transferred to the second module. In the second module, a PC was connected to the robot arm via an Ethernet cable. The PC was configured as a TCP/IP server and the robot arm was configured as a TCP/IP client. The server and client were communication each other by a speed of 125 Hz, so that the robot arm can be controlled in real-time. The server transformed the position data of the pumpkin fruits from the camera coordinates to the robot coordinates. In the third module, a commercial robot arm (universal robot, UR5, Denmark) was utilized to catch the target fruits.

4:30 PM - 4:45 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room D)

[4-1600-D-03] Handy Type Pig Weight Estimation System Based on Random Forest Algorithm

*Hsu Lai Wai[1], Kikuhito Kawasue[1], Khin Dagon Win[1], Kumiko Yoshida[2] (1. University of Miyazaki(Japan), 2. KOYO Plant Service(Japan))

Keywords: Xtion-2 Device, Laser Slit, Region Growing, Random Forest, Pig Weight Estimation

In every pig farm, manual pig weight measurement takes time and needs many labors. Generally, load cell is used in pig farms to measure the pig weight. That way of measurement is hard to guide pigs to the weighting machine. The most problem is having vibration when the pig is on the load cell. It causes the inaccuracy result in measuring the pig weight and takes at least 20 seconds to get the stable result. In addition to the pig weight, the labors measure the body length and girth of the pig to know how much changes in pig growth. It is difficult for labors to control the pigs during the measurement. At least two labors are needed to control the pig body. In case of manual measurement, the pig body must be straight to get the stable result since the pig takes different poses. Thus, the mouth of the pig is fixed with the steel wire to avoid pig movement during the pig measurement. That is a hard work for both labors and pigs in every pig farms. In order to cope with these problems, we have developed the handy type measurement system to get parameters to estimate the pig weight by just capturing the image of the pig in the pig farm. The pig body length is defined as the length between the head and tail along the spine of the pig body. The position behind the fore legs of the pigs is known as girth position of the pig. The size of a pig body area is also important in pig weight estimation.

These parameters are extracted automatically by our system, regardless of the posture of the pig.
In our system, Asus Xtion-2 Device is used to estimate pig weight. Laser slit is also used to align the direction of the pig body. Xtion-2 device contains RGB-D sensor and can provide 5M RGB resolution. Thus, clear depth image is captured with that device. That captured image is used as data in the estimation of pig weight.
Therefore, that system not only reduces works and time for labors in the pig farm but also releases pig struggling when guiding the pig to the load cell. After capturing depth image using Xtion-2 device, pig body to be measured is extracted automatically from that captured image. In extraction process of the pig body, Region Growing method is applied in our system. Region growing method can extract the target body robustly from the depth image. After extraction of the pig body, our system detects both 2-D data and 3-D data such as body length and girth to estimate the pig weight.
After extracting the parameters of the pig body of the captured image, Random Forest Algorithm, one of the machine learning method is applied to estimate the pig weight in our system. There are advantages of Random Forest Algorithm. Random Forest can be used for identifying the most important features from the training dataset. Therefore, Random Forest Algorithm is the appropriate method for measuring the pig weight in the practical condition of a pig farm. The estimated pig weight is accurate with the ground truth weight with the use of random forest method. The operator can know the estimated pig weight immediately by just capturing one image for the pig to be measured.

4:45 PM - 5:00 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room D)

[4-1600-D-04] Plant Disease Identification using Explainable Features with Deep Convolutional Neural Network

*Harshana Habaragamuwa[1], Yu Oishi[1], Katu Takeya[1], Kenichi Tanaka[1] （1. National Agriculture and Food Research Organization(Japan)）
Keywords: Plant disease identification , Explainable features, Convolutional Neural Network , Auto-encoder, Deep learning

Recently deep learning algorithms are widely used in agricultural applications such as disease identification. However, the most of these algorithms are black-box models, which means the users are unable to interpret (explain) what kind of features the Convolutional Neural Network (CNN) algorithm learned to perform the classification task. Without interpreting the learned features, users cannot verify whether the algorithm learned the correct features, this problem may lead to disastrous situations. Because of low interpretability, it is difficult to, improve the training data, gain new knowledge from the data, improve the architecture, or predict the behavior of the algorithm in different conditions. Our objective is to develop a deep learning algorithm which, in an intermediate stage creates explainable features that can be used to discriminate between a healthy and diseased leaf. We used the PlantVillage dataset which is a commonly used dataset for disease identification research, to develop and test our algorithm. This data set consists of leaf images (healthy and diseased) from plants such as tomato, potato, bell pepper, etc. The algorithm is made of three stages. The first stage is an unsupervised generative training using a variational auto-encoder. The second stage involves a supervised generative training using a variational auto-encoder and the final stage involves training a supervised classifier to discriminate between healthy and diseased leaves. The results were evaluated using the visual quality of the features which can be visualized in the second stage of the training. We also tested the final classification accuracy, because there is a compromise between interpretability (understandability) and fidelity (the accuracy of classification). The results of our visual outputs were easy to understand with compared to a conventional heat-map visualization. Our average classification accuracy was

92%, which may be acceptable given the level of interpretation supplied by our method. Our method can be used to find out the features which may be used to separates a healthy and diseased leaf with a low sacrifice to the final classification accuracy. In the agricultural field, this method will help in disease classification to improve algorithms and deficiencies in training datasets. Moreover, the disease experts can predict the behavior of this algorithm in different situations and they can gain knowledge about the features which are characteristics of plant disease. In the future, this algorithm would be extended to other fields where the safety is of paramount importance. Object identification in autonomous vehicles, food safety inspections, and poisonous plant identifications are perspective areas to extend our algorithm.

5:00 PM - 5:15 PM (Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room D)

[4-1600-D-05] Sensitivity and Dynamic Analysis of Microalgae Fuel Production System Using LCA

*Riaru ISHIZAKI[1], Ryozo Noguchi[2], Agusta Samodra Putra[1], Tofael Ahamed[2], Makoto M. Watanabe[3] (1. Graduate School of Life and Environmental Sciences, University of Tsukuba(Japan), 2. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan), 3. Algae Biomass and Energy System R&D Center, University of Tsukuba(Japan))

Keywords: Bio-production systems engineering, Microalgae, Concurrent engineering, Visualization, Standardization

The purpose of this research is to develop a data analysis system for microalgae that included upstream to downstream processes of production. Energy profit ratio (EPR) and life cycle assessment (LCA) were applied for evaluating production capability refer to output, quality besides output performances, cost, and delivery (QCD). A system approach is required to develop a data analytical platform to increase QCD performances at the different stages of microalgae production based on the concept of concurrent engineering. The forecasting of dynamic result changes could play a key role to data shearing at the different sub-unit of microalgae production system. The microalgae oil-production processes consisted of four sub-unit: open raceway pond (ORP), flocculation, drum filtration, and hydrothermal liquefaction (HTL). The system was based on the experimental data from the Minami-Soma pilot project. Three scenarios were established. Scenario 1 was built a new bioplant on an industrial site to produce a 17.48 kg/day bioclude, by processes algae-containing liquid (50 t/day) from a 0.1 ha ORP. Scenario 2 was built with the thermal power plant site and added the use of heat from there, and the wastewater to scenario 1. In scenario 3, the depth of the water changed from 0.2 to 0.4 meter and related equipment was scaled up to follow scenario 2. The calculated EPR was observed 0.57, 10.81, 10.41 for scenario 1, 2, 3, respectively. The primary contributor was discharged heat from the power plant for utilizing in the HTL process, and replacement of the wastewater treatment energy by microalgae. The EPR was considered from running energy that did not include the energy from the initial investment and input material production. The global warming potential with accumulated value for 100 years (GWP 100) was reported as 47.5, 53.4, 25.4 kg CO_2eq in CO_2 conversion per kg of biocrude for scenario 1, 2, 3, respectively. The acidification potential (AP) and eutrophication potential (EP) had similar trends. In scenario 2, the environmental impact was not changed compared to scenario 1. In this regard, construction of the wastewater treatment plant was added in the system boundaries. In addition, the depth of the ORP at the scenario 3 was doubled. Therefore, the environmental impact per product was observed half compare to scenario 2. The major cost of production was labor and depreciation costs of the HTL plants. Through the LCA-based system approach, microalgal production could be suggested for the best optimal production pattern in any site-specific requirement of environment for sustainability.

Oral Session | Others (including the category of JSAM and SASJ)
[4-1600-D] Other Categories (1)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room D (4th room)

[4-1600-D-06] An Aerial Weed Detection System for Green Onion Crops Using the You-Only-Look-Once (YOLO) Deep Learning Algorithm

Addie Ira Borja Parico[1], *Tofael Ahamed[2] (1. College of Agrobiological Resource Sciences, School of Life and Environmental Sciences, University of Tsukuba(Japan), 2. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan))

Keywords: You Only Look Once, Deep Learning, Weed Detection, Convolutional Neural Network, Unmanned Aerial Vehicle

Herbicide application is a common and inevitable method for preventing weed growth for some crops. Green onions are vulnerable to and significantly affected by weed infestation. However, herbicide contamination can pose as a food safety concern, especially in Japanese cuisine where green onions are typically eaten fresh. As a possible solution, an herbicide spraying system precisely targeting weeds while avoiding green onions was conceptualized. As a preliminary investigation, this study develops and evaluates the performance of what is referred to as the YOLO-WEED, a system that allows the smart detection of weeds through the utilization of unmanned aerial vehicles (UAVs) combined with You-Only-Look-Once (YOLO) deep learning algorithm. YOLO is a forerunner in terms of inference time in object detection, making it suitable for UAV applications. For the dataset, a five-minute UAV video was taken at altitude 4-5 meters at 0-1.3 m/s speed. Each frame from the UAV video were captured and cropped into tiles. 600 of these tiles were selected, annotated and split into training and validation dataset (450) and testing (150). After that, training, validation and testing were performed on YOLO-WEED with the GPU NVIDIA GeForce GTX 1060. IoU, which is the ratio between area of overlap and area of union of the bounding boxes of the ground truth object and the prediction, is the basis of true positive (TP), false positive (FP) and false negative (FN). Based on the TP, FP and FN, the following main performance metrics can be calculated: F1 score (with values 0 to 1) and mean average precision (with values 0 to 100 % with a threshold of 50% for IoU). Moreover, the detection speed expressed in frame per second (FPS) was also determined. YOLO-WEED demonstrated high detection speed (23.7 to 27.8 FPS) and remarkable performance, with mean average precision of 91.09 % and an F1 score of 0.85. YOLO-WEED was also tested on a cropped UAV video and the limitation of YOLO in detecting small objects was minimized. These results successfully show the effectiveness of the YOLO-WEED system for real-time UAV weed detection given its high speed and high accuracy in detection.

Proceedings of the 2019 International Joint Conference on JSAM and SASJ, and 13th CIGR VI Technical Symposium joining FWFNWG and FSWG Workshops

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Addie Ira Borja Parico[1] Tofael Ahamed[2*]

[1]College of Agro-biological Resource Sciences, University of Tsukuba, Japan
[2]Faculty of Life and Environmental Sciences, University of Tsukuba, Japan

*Corresponding author: tofael.ahamed.gp@u.tsukuba.ac.jp

ABSTRACT

Herbicide application is a common and inevitable method for preventing weed growth for some crops. Green onions are vulnerable to and significantly affected by weed infestation. However, herbicide contamination can pose as a food safety concern, especially in Japanese cuisine where green onions are typically eaten fresh. As a possible solution, an herbicide spraying system precisely targeting weeds while avoiding green onions was conceptualized. As a preliminary investigation, this study develops and evaluates the performance of what is referred to as the YOLO-WEED, a system that allows the smart detection of weeds through the utilization of unmanned aerial vehicles (UAVs) combined with You-Only-Look-Once (YOLO) deep learning algorithm. YOLO is a forerunner in terms of inference time in object detection, making it suitable for UAV applications. For the dataset, a five-minute UAV video was taken at altitude 4-5 meters at 0-1.3 m/s speed. Each frame from the UAV video were captured and cropped into tiles. 600 of these tiles were selected, annotated and split into training and validation dataset (450) and testing (150). After that, training, validation and testing were performed on YOLO-WEED with the GPU NVIDIA GeForce GTX 1060. IoU, which is the ratio between area of overlap and area of union of the bounding boxes of the ground truth object and the prediction, is the basis of true positive (TP), false positive (FP) and false negative (FN). Based on the TP, FP and FN, the following main performance metrics can be calculated: F1 score (with values 0 to 1) and mean average precision (with values 0 to 100 % with a threshold of 50% for IoU). Moreover, the detection speed expressed in frame per second (FPS) was also determined. YOLO-WEED demonstrated high detection speed (23.7 to 27.8 FPS) and remarkable performance, with mean average precision of 91.09 % and an F1 score of 0.85. YOLO-WEED was also tested on a cropped UAV video and the limitation of YOLO in detecting small objects was minimized. These results successfully show the effectiveness of the YOLO-WEED system for real-time UAV weed detection given its high speed and high accuracy in detection.

Keywords: You Only Look Once, Deep learning, Weed detection, Convolutional neural network, Unmanned aerial vehicle

1. INTRODUCTION

Weed control is important for green onion crops as weeds can easily outcompete them because they grow more rapidly, thus, shading the crop and competing for nutrients and water (Gilreath et al., 2008; "Green Onions," 2016; Hewson and Roberts, 1973). The largest expenditures in green onion production in terms of pest management, after all, come from weed control (Norsworthy et al., 2007).

Although elimination of weeds is important, herbicide should not be applied generously to green onions for multiple reasons. One is that herbicide contamination can pose as a food safety concern, especially in Japanese cuisine where green onions are typically eaten fresh. At the agronomy's side, herbicides can

reduce the height, density and yield of green onion when applied during crop emergence in at least 1-2 years (Norsworthy et al., 2007). And from the environment's viewpoint, excessive application of agrochemicals leads to runoff, which can negatively impact the quality of ground water or even contaminate the fisheries. Thus, as much as possible, herbicide application on onion should be minimized. Fortunately, spraying systems can be more precise and improved with deep learning-based weed detection systems.

コメントの追加 [PAIB1]: Add the food safety concern

Machine learning is a set of algorithms that does not need explicit programming to perform a goal by inferencing patterns from input data. Deep learning, on the other hand, is a sub-field of machine learning that is about learning in multiple levels of abstraction in order to model complex relationships among data such as images, sound or text (Deng and Yu, 2014). These layers of non-linear information processing are often called neural networks. In this study, the deep learning algorithm used is YOLO (You-Only-Look-Once), an object detection system that uses a single convolutional neural network, called Darknet, to simultaneously predict the bounding box coordinates and class probabilities straight from an image (Redmon et al., 2015). Its remarkable speed has attracted attention from the deep learning field, boasting a 22 millisecond-inference time with a GeForce GTX Titan X (Redmon and Farhadi, 2018). This makes it highly suitable for real-time applications, such as UAV. However, the cost of increasing the speed is reduced accuracy. Thus, in this study, a YOLO-based weed detection system, which will be called YOLO-WEED from hereon, was developed and evaluated using a UAV video as source of dataset.

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2. MATERIALS AND METHODS

2.1. Data Acquisition

Video acquisition was done in a green onion field with weed incidences in Yatabe, Tsukuba-shi, Ibaraki-ken, Japan (36°00.414'N 140°05.349'E) on a clear day on May 2019 using DJI Phantom 3 Pro. The video was five minutes long recorded at 5-meter altitude in a very slow speed (0-1.3 m/s).

コメントの追加 [PAIB4]: I think this is not accurate. Check the right coordinates

2.2. Dataset Preparation

The video was divided into image frames by using VLC to capture the video frames per second (one capture for every 24 frames). All screen captures were divided into 96 tiles (8 rows, 12 columns) so that weeds are easier to identify and annotate. Total of 600 images (size 341 x 270 pixels) with both green onion and weeds of differing lighting, clarity, incidence and object sizes were randomly selected. These images were divided into two sets: training & validation (450 images) and testing (150 images). Weeds in the images were labeled with an open-source software BBox-Labeling-Tool (Qiu, 2017). Then, the generated labels were converted into YOLO format. To test YOLO-WEED on videos, a cropped UAV video of resolution 864 x 688 was prepared.

2.3. Weed detection with You-Only-Look-Once (YOLO) algorithm

To set up the weed detection system, Darknet (Redmon, 2016) was downloaded from a stable and improved Github repository of Darknet (AlexeyAB, n.d.). GPU-enabled YOLOv3 (Redmon and Farhadi, 2018) was compiled in Windows 10 operating system using Visual Studio with the dependencies installed (CUDA version 10.1.168, OpenCV 3.4.0, cuDNN 10.1). The hardware used has the following specifications: Quad-core Intel® Core ™ i7-7700HW @ 2.80 GHz, NVIDIA GeForce GTX 1060 and 16GB RAM.

2.3.1. Metrics for evaluating the performance of YOLO

The performance of YOLO was evaluated based on the metrics used in the Pascal VOC Challenge (Everingham et al., 2010). The first metric is Intersection over Union or IoU (equation 1), which is the

ratio between the area of overlap and the area of union of the bounding boxes of the prediction and the ground truth object:

For a detection to be considered as True Positive (TP), or ground truth objects that were correctly identified, IoU should be equal to or greater than 0.5, deliberately set this low to account for human errors in creating the bounding boxes for the ground truth, for example, if a plant has radial stems but most of its vegetative parts are at the center, is somewhat subjective. False positive (FP) detections will be having IoU values under 0.5. False negative (FN) detections are ground truth objects that were completely missed by the predictions or those assigned with low confidences in predictions (eliminated by a certain threshold, which is in this case 0.25).

Table 1. Formulas for the performance metrics used to evaluate YOLO-WEED

Performance Metric	Equation number
$IoU = \frac{area\ of\ overlap}{area\ of\ union}$	(equation 1)
$R = \frac{TP}{TP + FN}$	(equation 2)
$P = \frac{TP}{TP + FP}$	(equation 3)
$F1 = \frac{2 \cdot P \cdot R}{P + R}$	(equation 4)
$mAP = \int_0^1 P(R)dR$	(equation 5)

The second metric is Recall (equation 2), or in other words, the sensitivity of the weed detection system. This metric defines the proportion of true positive detections to total ground truth objects. The third metric is Precision (equation 3), which is the proportion of the true positive detections to all positive detections. Next is F1 score, as seen in (equation 4), which quantifies the overall performance of detection by incorporating both precision and recall. Another metric is mean average precision or mAP (equation 5), the area under the precision-recall curve. It is an alternate metric to F1 score in terms of summarizing precision and recall. This metric is often used during the training to select which weights fit the model.

2.3.2. Training YOLO

Default configurations intended specifically for custom object detection for initial training of YOLOv3 (AlexeyAB, n.d.) were set initially with the pre-trained weights for darknet53 (Redmon, 2016). For each 100 iterations, weights were generated during the training process. To determine if training should be halted (to avoid overfitting), the mAPs and loss function (equation 6) chart were enabled and examined. The training was terminated when the average loss no longer decreases as much after many iterations and when the highest mAP has been achieved. For this case, maximum iteration number of 2000 was enough.

$$loss = \lambda_{coord} \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{ij}^{obj} [(x_i - \hat{x}_i)^2 + (y_i - \hat{y}_i)^2]$$
$$+\lambda_{coord} \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{ij}^{obj} \left[\left(\sqrt{w_i} - \sqrt{\hat{w}_i}\right)^2 + \left(\sqrt{h_i} - \sqrt{\hat{h}_i}\right)^2 \right]$$
$$+ \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{ij}^{obj} (C - \hat{C}_i)^2 \qquad \text{(equation 6)}$$
$$+ \lambda_{noobj} \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{ij}^{noobj} (C - \hat{C}_i)^2$$
$$+ \sum_{i=0}^{S^2} \mathbb{1}_{i}^{obj} \sum_{c \in classes} (p_i(c) - \hat{p}_i(c))^2$$

where $\mathbb{1}_i^{obj}$ is when an object appears in cell i and $\mathbb{1}_{ij}^{obj}$ is when the jth bounding box predictor in cell i is "responsible" for that prediction

2.3.3. Validation and testing YOLO

The purpose of validation is to evaluate the performance of the weights generated from the training. Testing is to make sure overfitting is minimized, which means the YOLO-WEED using the generated weights can also detect weeds with other datasets. Validation and testing in this paper was based on the bounding box evaluation of Pascal VOC Challenge (Everingham et al., 2010). Testing was divided into two parts: testing (1) with test images and (2) with the cropped UAV video.

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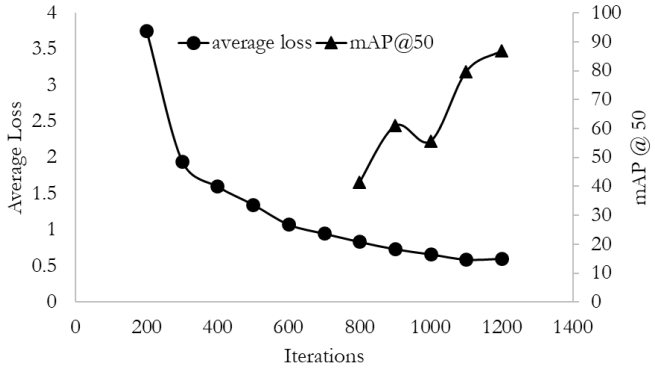

Figure 1. Loss function and mean average precision values (at 50 percent threshold for IoU) during the training at network resolution of 416 x 416, learning rate = 0.001, decay = 0.0005, momentum = 0.0005 and batch size = 64

3. RESULTS

3.1. Training YOLO for weed detection

YOLO was trained with 450 annotated images to detect instances of weeds. Weights were generated every 100 iterations during training. The change in average loss started to become negligible at iteration

1200 so training was stopped at that point. Weights with the lowest loss and highest mAP after the early stopping point (around iteration = 800) were selected for further validation. As seen in *Figure 1*, highest mAPs and lowest losses were achieved at iteration 1100 and 1200.

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3.2. Validating YOLO-WEED

The weights were validated using the performance metrics mentioned in Section 2.3.1. From the training, weights from iteration 1100 and 1200 had the highest performance. And it is confirmed in validation that weights from iteration 1200 may be most suitable for use as characterized by high scores in Average IoU, mAP, Precision, Recall and F1 (refer to *Figure 2*). In addition to this, detection speed at the said iteration was 23.7 FPS, which is deemed enough for standard frame rates of videos (24 FPS).

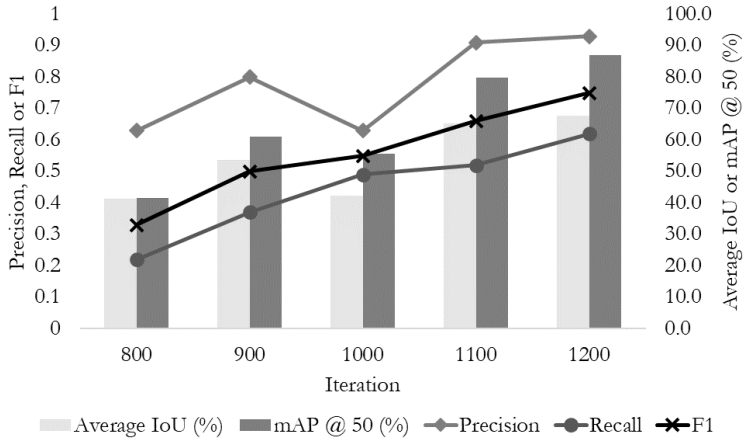

Figure 2. Validation results among weights from iterations on and after the early stopping point. A threshold of 50 percent for the IoU (Intersection over Union) is applied for the mAP (mean average precision).

3.3. Testing YOLO-WEED

Well-performing detection in validation may reflect overfitting so final testing was done with a separate set of 150 annotated images. It is confirmed with high scores in performance metrics that overfitting is minimized at iteration = 1200 (*Table 2*).

In terms of F1-score and mAP @ 50, it can be construed that the weed detection system is well-performing in comparison with YOLO that used official datasets: mAP@50 of 55.3 percent using COCO Dataset (Redmon and Farhadi, 2018) and mAP@50 of 78.6 percent using PASCAL VOC 2007 dataset (Redmon and Farhadi, 2017). However, the YOLO-WEED was only trained with one class, which explains its better metrics compared to YOLO being tested with COCO and PASCAL VOC 2007 datasets.

Table 2. Results from Testing the Trained Network with 150 Test Annotated Images Using Weights from Iteration = 1200, Network Resolution of 416 X 416

	Value
Average IoU	68.28 %
Precision	0.94
Recall	0.78
F1-score	**0.85**
mAP @ 50*	**91.09 %**

*at 50 percent threshold for IoU

Precision has a very high value of 0.94, which signifies that a remarkable amount of the total positive detections are *true* positive detections. This means that YOLO was able to distinguish green onion from weeds, thus, very little false positive predictions were generated. Recall, however, is relatively lower than precision, which implies that 22 percent of the ground truth objects were not detected at all. This is possibly due to the fact that YOLO is disadvantageous in detecting small objects (Du, 2018). It is also possible that there were not enough weed objects during the training that were occluded, thus, detection of occluded weeds may have lower confidence and were eliminated by the confidence threshold.

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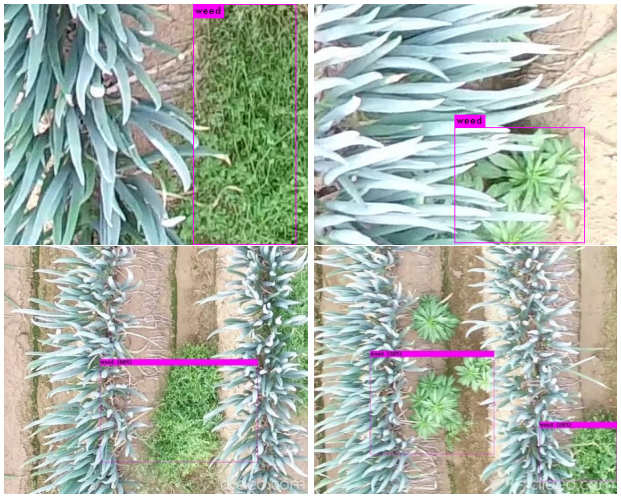

Figure 3. (Top Left) Test image with instance of "weed" object is enclosed in a bounding box of 98 percent confidence at 27.8 FPS. (Top Right) Test image with occluded "weed" object was still detected at 33 percent confidence at 29.4 FPS. (Bottom Left) An image frame from the tested cropped video with instance of "weed" object detected at 88 percent confidence. (Bottom Right) Another image frame from the tested cropped video with smaller weeds detected at relatively lower confidence (28 percent and 38 percent), including a false negative detection.

3.4. Testing YOLO-WEED on UAV videos

As a final test, the YOLO-WEED was tested on a cropped video (864 x 688 resolution). The detection was done at 512 x 512 network resolution of YOLO. *Figure 3* shows some screen captures of the weed detections, which occurred at approximately 24 FPS. This further proves the high potential of YOLO in

real-time object detection in videos. However, there are still some false negative detections for smaller weeds.

Before testing with the cropped video, YOLO-WEED was first tested on a full-resolution UAV video (4096 x 2160). However, weeds were not successfully detected of which might be due to the spatial constraint of YOLO in detecting extremely small objects. The implementation of the same value for threshold for all object sizes may also contribute to false negative detections. In this paper, a threshold of 0.5 was implemented for IoU. However, small objects' IoU can deviate largely with just slight difference in pixels between the ground truth and prediction (Russakovsky et al., 2015). For example, consider an object of size 10 x 10 pixels with a corresponding detection bounding box of 20 x 20 pixels that fully encloses the object. The IoU in this case will be 0.25, which is eliminated from the threshold of 0.5. Another possible source of problem is the loss function of YOLO, which treats errors the same in all sizes of bounding boxes, big or small. A small error in a large box is generally negligible but a small error in a small box has a bigger effect on the IoU.

4. CONCLUSION

This study developed and evaluated the performance of YOLO-WEED, a system that allows the detection of weeds in UAV video frames through the utilization of the deep learning algorithm YOLO. It demonstrated high speed (23.7 to 27.8 FPS), making it suitable for real-time weed detection for green onion fields. Furthermore, it showed remarkable performance with test images, having a mean average precision of 91.09 percent and an F1 score of 0.85. Lastly, YOLO-WEED performed fairly with the cropped UAV video, having the limitation of YOLO in detecting small objects minimized.

On the other hand, there are still things to improve for YOLO-WEED: the detection of small weeds and the robustness of the detection system. For the first one, training dataset should be collected at lower altitudes (1 to 2 meters) to reduce the need to crop the UAV video, thus, the small weeds will appear larger. This will increase the recall score by preventing false negative detections. To increase the robustness of weed detection, one thing that can be done is to perform data augmentation, of which diversifies the training dataset by generating images (of different scale, viewpoint, rotation, exposure, clarity, resolution and texture) from the same set of original training dataset. Another is to discard training photos that may be considered "difficult" for annotation (Russakovsky et al., 2015) which is often a source of bias in calculation of IoU.

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Oral Session | Others (including the category of JSAM and SASJ)
[4-1600-D] Other Categories (1)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room D (4th room)

[4-1600-D-07] A Deep Learning and MSM Machine Learning System for Recognition of Weed Infestation in Cabbage Field Using Unmanned Aerial Vehicle

*Tofael Ahamed[1], Yan Zhang[1], Linhuan Zhang[1], Ryozo Noguchi[1] （1. Faculty of Life and Environmental Sciences, University of Tsukuba(Japan)）

Keywords: Deep Learning , Convolution Neural Network (CNN), Mutual Subspace Method (MSM) , Precision Agriculture, Spot Spraying

Cabbage is susceptible to grow due to weeds incidence and requires large amounts of herbicides in the small-scale Japanese farms. In precision application of herbicides, it is required to recognize the classifiers to minimize herbicides application. Therefore, the purpose of this research is to deal with recognition of weed infestation in the cabbage field using two classifiers: cabbage and weeds. A DJI Phantom UAV was flown with an onboard 4K RGB camera from 2m heights to identify the weed incidence in a cabbage field located at the Ibaraki Prefecture of Japan. Two videos were used and converted to figures: one for training and other for testing. In the pre-process stage, each original image with size of 1920x1080 was divided into 250x250 small size sub-graphs using a sliding window, with step of 250. Each sub-image could be defined as: cabbage and weeds. In the training, 676 datasets for cabbage, 667 datasets for weeds were taken from sub-images. Alexnet CNN deep learning and Mutual Subspace Method (MSM) machine learning were used to find the recognition of the two classes.The accuracy for recognizing the classifiers using MSM was 61%. To improve the accuracy of MSM, Histogram Oriented Gradient (HOG) method was used with MSM. The recognition accuracy was increased to 88% using MSM-HOG algorithm. The overall accuracy was achieved 94%for recognizing the classifiers using AlexNet CNN.In the deep learning process, the enlarging dataset and learning technology can be inherit with AlexNet CNN and MSM-HOG. Further research will be carried out using weights in each of the layer to improve the accuracy of the classifiers. This deep-learning approach has the potential to add in the spot sprayer for real-time application to minimize herbicides for UAV.

A Deep Learning and MSM Machine Learning System for Recognition of Weed Infestation in Cabbage Field Using Unmanned Aerial Vehicle

Tofael Ahamed[1*], Yan Zhang[2], Linhuan Zhang[2], Ryozo Noguchi[1]
[1]Faculty of Life and Environmental Sciences, University of Tsukuba, Japan
[2]Graduate School of Life and Environmental Sciences, University of Tsukuba, Japan

*Corresponding author: Email: tofael.ahamed.gp@u.tsukuba.ac.jp

ABSTRACT

Cabbage is susceptible to grow due to weeds incidence and requires large amounts of herbicides in the small-scale Japanese farms. In precision application of herbicides, it is required to know classifiers for spot spraying to minimize herbicides application for enabling GAP practices. The purpose of this research is to deal with recognition of weed infestation in the agricultural field, especially for cabbage with two classifiers: cabbage and weeds. Alexnet CNN deep learning and Mutual Subspace Methods (MSM) were used to find out the recognition of the classes. The overall accuracy was achieved 94% for recognizing the classifiers. Further research will be carried out using weights in each of the layer to improve the algorithms and accuracy of the classifiers.

Keywords: Deep Learning, CNN, MSM, Precision Agriculture, Spot Spraying

1. INTRODUCTION

Most of the weeds classification techniques, which are referred to the ground carrier, and the complex image processing algorithms are used for feature extraction and then classified. This makes the method with poor adaptability and lack of robustness. Convolutional Neural Network (CNN) has the potential for recognizing classifiers. On the other hand, MSM has the robustness with fastest computational time for recognizing classifiers (Yan et al. 2018). The CNN has made a rapid development since its appearance in the field of deep learning. It has shown excellent performance using MSM and HOG for shorter time in the field of image recognition, target location and detection. At present, CNN has been studied and applied in many fields (Zheng et al. 2017, Zhao et al. 2018). The well-known AlexNet CNN architecture can be utilized in combination with a sliding window object proposal technique. In this paper, a low-altitude cabbage images were captured by UAV. The CNN and MSM methods are proposed for weed classification considering density of weed infestation.

2. MATERIALS AND METHODS

2.1 Convolution Neural Network (CNN)

CNN is a multi-layer data processing algorithm, which is originally inspired by neural mechanisms underlying visual system and was designed in view of the two-dimensional shape's identification. The convolution layer is the core part of the convolutional neural network. Its main function is to extract local features of the input through the fixed-step movement of the convolution kernel. The core of the convolutional layer operation is to reduce unnecessary weight connections, introduce sparse or partial connections, and bring the weight sharing strategy to reduce the number of parameters greatly. The most common mathematical expression of convolutional layer is as follows:

$$x_j^n = f\left(\sum_{i \in M_i} x_i^{n-1} * k_{ij} + b_j^n\right) \quad (1)$$

where x_j^n represents the j th feature map of the n th convolutional layer, $f(.)$ represents the activation function, M_i represents the selected input feature map combination, x_i^{n-1} represents the i th output feature of the $n-1$ th layer, and "*" represents the convolutional operation, k_{ij} represents the convolution kernel between the i th feature map of the previous layer and the j th feature map of the current layer, and b_j^n is the bias of the current layer. The pooling layer obtains the invariant properties of the higher level by the function transformation of the non-overlapping rectangular region on the upper output characteristic graph. The mathematical expression of the pooling layer is as follows:

$$x_j^n = f(\beta_j^n * down(x_j^{n-1}) + b_j^n) \quad (2)$$

Where x_j^n represents the j th feature map of the n th pooling layer, $f(.)$ represents the activation function, $down$ represents the pooling process, and β_j^n is a multiplicative weight value, the general value of 1; b_j^n is additive bias, the general value of 0 matrix.

2.2 Mutual Subspace Method (MSM) and HOG

MSM is the extension of the Subspace Method (SM). Classifying a set of input pattern vectors into several classes based on multiple canonical angles between the input subspace and class subspaces (Figure 1. a). HOG is an edge orientation histograms based on the orientation of the gradient in localized region that is called cells. It is easy to express the rough shape of the object and is robust to variations in geometry and illumination changes with MSM (Figure 1. b).

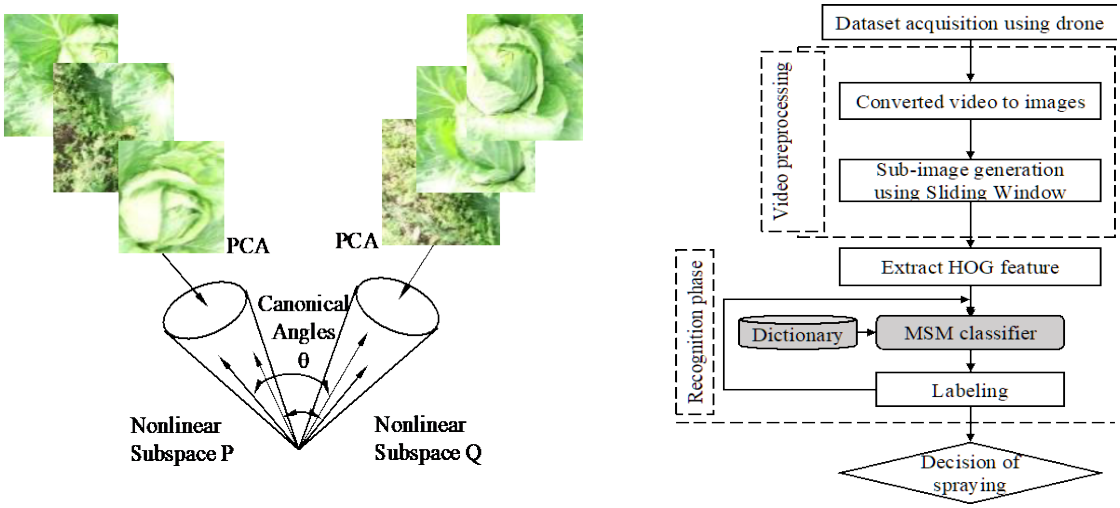

Figure 1 a) Two sets of images using MSM b) Online recognition: HOG & MSM classifiers

2.2 Data Acquisition System

In the cabbage filed, A DJI Phathomon UAV was flown with an onboard 4K RGB camera from 2m heights. From the view of uses, the cabbage is with high production and it's a leafy vegetable, the precision spray for broadleaf type vegetables is more meaningful than others. Two videos were used and converted to figures: one for training and other for testing.

Figure 2 Classes for training and testing for weeds and cabbage including sliding window for sub-images in the original image

The data model AlexNet was used. In the pre-process stage, each original image with size of 1920x1080 was divided into 250x250 small size sub-graphs with a sliding window, with step of 250. Each sub-image can be defined as: cabbage and weeds (Figure 2). In the training, 676 datasets for cabbage, 667 datasets for weeds were taken from sub-images (Table 1).

Table 1 Date sets (data numbers) used for training and testing:

Category	Original image	Sub-images	
		Cabbage	Weeds
Training	136	676	667
Testing	132	303	369

3. RESULTS AND DISCUSSION

The accuracy for recognizing the classifiers using MSM was 61% and 88% using MSM and MSM-HOG (Figure 3. a and b). The overall accuracy was achieved 94% for recognizing the classifiers using AlexNet CNN (Figure 3. c and d). Further researches need to be carried to increase the classifiers for UAV-based autonomous sprayer development. Real-time recognize weeds density level using deep learning model. In the deep learning process, the enlarging dataset and learning technology can be inherit with AlexNet CNN and MSM-HOG.

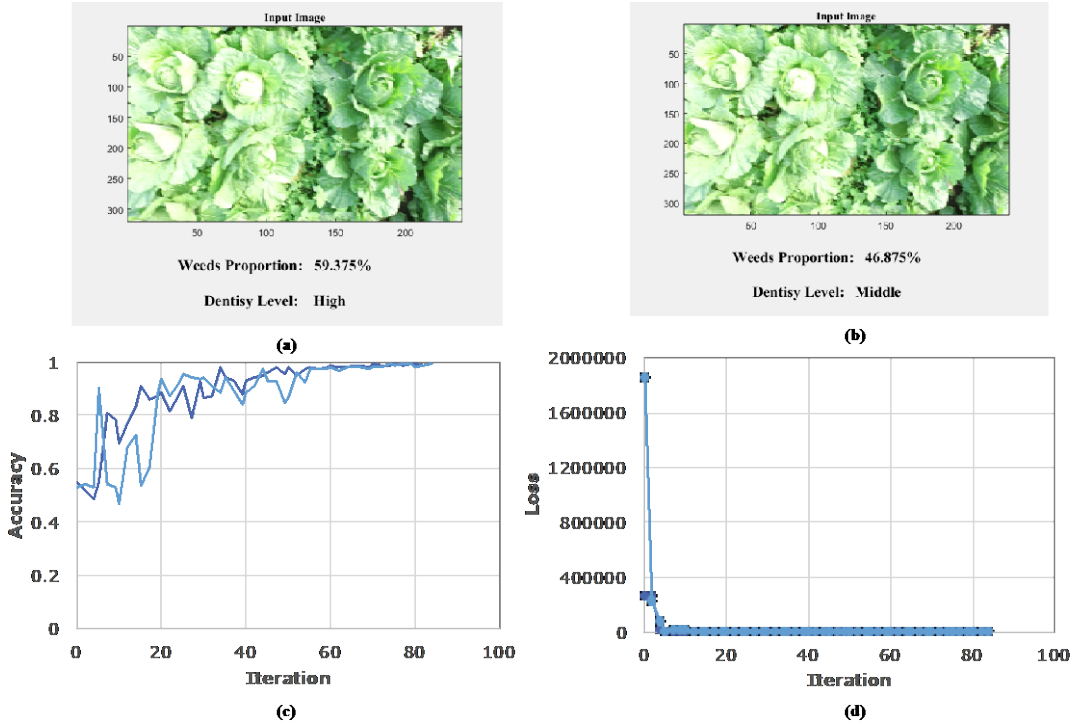

Figure 3 (a and b) MSM and Hog-based accuracy relates weed density level (c and d). Accuracy and loss value in different iterations during training of datasets

In further research, in each of the 250x250 small size image, weight will be set for each class: graphs belong to class of cabbage with weight 1; graphs belong to class weeds with weight 0.5. Finally, a total weight can be calculated and the density level can be judged on-line by comparing a level standard.

4. CONCLUSION

The low-altitude images were taken from a UAV for classification of weeds using AlexNet CNN and MSM-HOG. This deep-learning approach has the potential to add in the spot sprayer for real-time application to minimize herbicides from UAV sprayers. The machine learning systems and inheritance knowledge could help in development of autonomous UAV-sprayer.

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Oral Session | Others (including the category of JSAM and SASJ)
[4-1600-D] Other Categories (1)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room D (4th room)

[4-1600-D-08] Mallard Navigation Using Unmanned Ground Vehicles, Imprinting, and Feeding

*Hirokazu Madokoro[1], Satoshi Yamamoto[1], Hanwool Woo[1], Kazuhito Sato[1] (1. Akita Prefectural University(Japan))

Keywords: rice-duck farming, feeding, imprinting, mallards, navigation, unmanned ground vehicle

This study was conducted to develop an unmanned ground vehicle (UGV) that navigates mallards to achieve high-efficiency rice–duck farming. This paper presents two navigation approaches and fundamental experiments to test them using a UGV. As the first approach, we used imprinting applied to baby mallards. Baby mallards, after hatching, exhibit following behavior to a UGV after imprinting. One week after hatching, baby mallards show wariness against an imprinted target object. Experimentally obtained observation results revealed the importance of providing imprinting immediately after hatching. As the second approach, we used feed placed on the top UGV body. Experimentally obtained results showed that adult mallards exhibited wariness not only against the UGV, but also against the feed box. After relieving wariness with provision of more than one week time to become accustomed, adult mallards ate feed in the box on the UGV. However, they ran away immediately at a slight movement of the UGV. We confirmed the necessity of imprinting to baby mallards for actualizing navigation because adult mallards are alerted by the UGV.

Mallard Navigation Using Unmanned Ground Vehicles, Imprinting, and Feeding

Hirokazu Madokoro[1], Satoshi Yamamoto[1], Hanwool Woo[1], and Kazuhito Sato[1]

1.Department of Intelligent Mechatronics, Akita Prefectural University, Japan

E-mail :madokoro@akita-pu.ac.jp

ABSTRACT

This study was conducted to develop an unmanned ground vehicle (UGV) that navigates mallards to achieve high-efficiency rice-duck farming. This paper presents two navigation approaches and fundamental experiments to test them using a UGV. As the first approach, we used imprinting applied to baby mallards. Baby mallards, after hatching, exhibit following behavior to a UGV after imprinting. One week after hatching, baby mallards show wariness against an imprinted target object. Experimentally obtained observation results revealed the importance of providing imprinting immediately after hatching. As the second approach, we used feed placed on the top UGV body. Experimentally obtained results showed that adult mallards exhibited wariness not only against the UGV, but also against the feed box. After relieving wariness with provision of more than one week time to become accustomed, adult mallards ate feed in the box on the UGV. However, they ran away immediately at a slight movement of the UGV. We confirmed the necessity of imprinting to baby mallards for actualizing navigation because adult mallards are alerted by the UGV.Start from here.

Keywords: rice-duck farming, feeding, imprinting, mallards, navigation, unmanned ground vehicle

1. INTRODUCTION

Rice-duck farming is an environmentally friendly rice cultivation method that employs neither chemical fertilizers nor pesticides. Although hybrid ducks are generally used for rice-duck farming, farmers in northern Japan use mallards because of their utility value as a livestock product. For this study, we specifically examine rice-duck farming using mallards considering regional characteristics. Fig. 1 depicts rice-duck farming using mallards.

Since ancient times, mallards have been domesticated as poultry for human consumption. Mallards are used not only for rice-duck farming, but also for meat because their smell is not strong. Mallards eat leaves, stems, seeds, and shells of plants. For weeding and pest control, mallards eat not only aquatic weeds such as itEchinochloaesculenta, itCyperusmicroiria, and itJuncuseffuses, but also aquatic insects such as itLissorhoptrusoryzophilus, itSogatellafurcifera, itNilaparvatalugens, itLaodelphaxstriatellus, but also river snails in a paddy field. Mallard movements in a paddy field also produce positive effects of full-time paddling. For weed prevention, turbid water suppresses photosynthesis of weeds below the surface. Moreover, mallards not only provide feces for nutrients of growing rice, but also contact rice during movements as a stimulus. A paddy field is a place of abundant water and life for mallards [1]. Moreover, the grown paddy rice can provide refuge from natural enemies.

This study was conducted to develop an unmanned ground vehicle (UGV) that navigates mallards to achieve high-efficiency rice-duck farming. As a navigation method used for mallards, we examined three approaches: imprinting, pheromone, and feeding. This paper presents basic navigation experiments of imprinting and feeding using a UGV.

Figure 1: Rice-duck farming using mallards.

Figure 2: Stepping pond: paddy rice is eaten by mallards.

2. NAVIGATION METHODS

In a paddy field, mallards often concentrate in a specific area because of a swarm habit. Some areas therefore have persistent weeds because mallards do not disperse. Moreover, a stepping pond occurs, as depicted in Fig. 2. Mallards eat paddy rice if weeds are insufficient. Moreover, as depicted in Fig. 2, a stepping pond occurs where all the paddy rice has been eaten by mallards. Mallards do not weed a whole paddy field uniformly. Therefore, farmers must weed them using a weed removing machine. As a different approach, some farmers use feed to navigate mallards. The difficulty of this approach is the necessity of human burdens, especially for large paddy fields. For this study, we examined three navigation approaches used for mallards: imprinting, pheromone tracking, and feeding.

Imprinting is a unique behavior observed in nidifugous birds such as ducks, geese, and chickens [2]. Imprinting is a contacting and following response to a stimulus that is received for the first time during a short period after hatching. Moreover, imprinting is enhanced for running and following in response to sounds or moving shadows. For this study, we specifically examined imprinting-based navigation. We used a UGV as an imprinting target for baby mallards.

Pheromones are chemicals that promote changes in behavior and development of conspecific individuals after being produced inside the body and secreted outside the body [3]. Pheromones are used mainly when insects communicate with conspecific individuals. Although no pheromone is available to navigate mallards, we consider indirect navigation using insects favored by mallards with pheromone. Specifically, we devised an indirect usage that navigates mallards using insects that are gathered to a pheromone trap attached to a UGV. Although baby mallards attempt to eat insects, adult birds have no interest in them. We consider that the efficiency of this approach decreases along with mallard development. For this study, we conducted no experiments using pheromone-based navigation because of the difficulty of the procedures using insects and the weak overall effects.

For rice-duck farming, breeders use feed to collect ducks. Breeders give minimum feed for ducks because ducks stop eating weeds if too much feed is given. We expect that feeding-based navigation is effective for adult mallards because imprinting can only be performed during the baby mallard period. Yamada et al. tested the effects of feed learning and navigation for hybrid ducks. However, they described no test for feed learning for mallard navigation. For this study, we specifically examined the method of navigating mallards following the use of feed combined with a UGV.

Figure 3: Inside (left) and outside (right) of the mallard farm.

Figure 4: Mallard eggs (left) and incubator (right).

3. IMPRINTING-BASED NAVIGATION

3.1 Experiment setup

For this experiment, we attempted imprinting of baby mallards after a hatch. We obtained eggs from a mallard farmer. Fig. 3 depicts the outside and inside of the mallard farm.

Figure 4 depicts the mallard eggs and an incubator (MX-20; Autoelex Co. Ltd.) that we used for a hatch. We divided 18 eggs into four groups because we shifted the hatching date in two-day intervals. We set the temperature and humidity in the incubator respectively to 37.5 deg and 45.0%. The bottom incubator plate includes a slider to roll the eggs periodically. We set the rolling frequency to one-hour intervals. We stopped the rolling approximately one week before the predicted hatching date. Simultaneously, the humidity was increased to 65%. The left panel of Fig. 5 depicts a baby mallard immediately after hatching. We kept the baby mallards in the incubator until their feathers were dry. After drying, we moved them to a breeding cage, as depicted in Fig. 5 right. We kept them warm in the cage using an electric heater.

The left panel of Fig. 6 depicts a 3D mallard model used for imprinting. After creating the model using a 3D printer, we put it on the UGV as depicted in the right panel of Fig. 6. The model was made of acrylonitrile butadiene styrene.

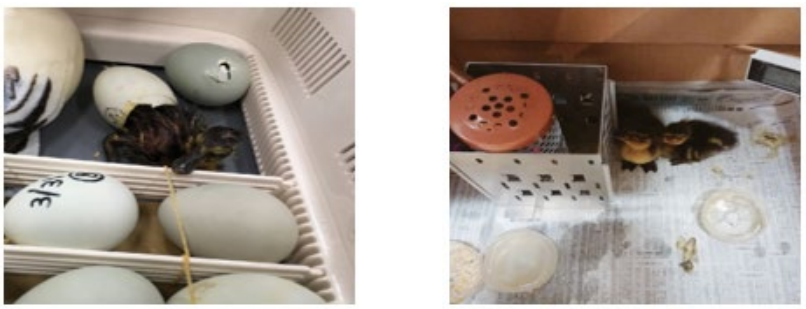

Figure 5: Baby mallard after hatching in incubator (left) and moving to a cage after drying of its feathers (right).

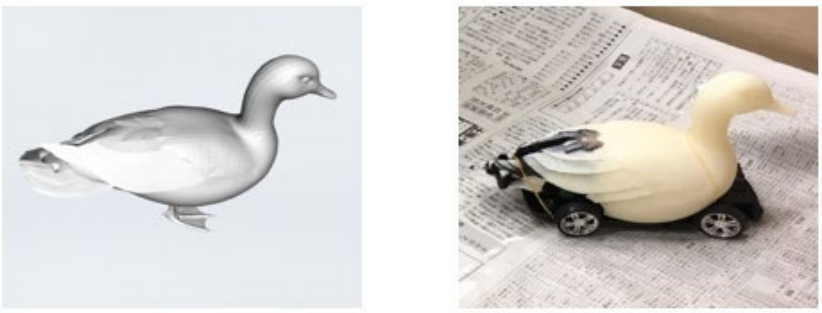

Figure 6: 3D mallard model (left) and mounting on UGV (right).

3.2 Experiment results

We applied imprinting sequentially to three mallards. We manually moved the UGV in the cage during 3 hr in front of a baby mallard. After imprinting, the baby mallard attempted to follow the UGV. Subsequently, we observed that the baby mallard changed responses of calling patterns according to UGV movements. The baby mallard moved near the electric heater when the UGV stopped.

We applied imprinting to the second baby mallard, which hatched two days later, with similar stimulation patterns and procedures. Although the second baby mallard followed the UGV, both were interested in each other. Our observations suggest that the interest between them was higher than that for the UGV. Therefore, we put a partition in the cage to separate them. First, they attempted to cross the partition. We showed the UGV to each baby mallard in their separated zone for enhanced imprinting. They continued the following behavior against the UGV. Subsequently, we added the third baby mallard to the cage after installing a partition. The imprinting procedure for the third baby mallard was similar to that used for the former two baby mallards.

For observing the following behavior, we moved the three baby mallards and the UGV from the cage to the test file with the size of 2.0 m2. Fig. 7 depicts time-series images of this experiment. The four sides of the test field were surrounded by wooden boards. As an objective after imprinting, the baby mallards followed a UGV that moved slowly. They continued following the UGV after increase of the velocity.

Imprinting among baby mallards after hatching occurred in a cage because they moved frequently. Based on the experiment for baby hybrid ducks conducted by Yamada et al. [4, 5], we considered that imprinting was enhanced for separating baby mallards because they spent time longer with the UGV together. Moreover, imprinting of individuals was effective because the calling sound volume of separated baby mallards was greater than that of the gathered baby mallards.

Figure 7: Following behavior displayed after imprinting.

Figure 8: UGV used for this experiment.

We attempted imprinting to baby mallards at one week after hatching using a similar procedure with the UGV. We confirmed that baby mallards falsely recognized the UGV as an enemy. Moreover, we observed that they avoided the UGV with a big call. Actually, mallards reach a peak sensitive period at 15 hr after hatching. Subsequently, the imprinting effect is reduced considerably. For the UGV, the interest for baby mallards arose at more than one week after hatching because the socalled critical period is weaker than that of baby mallards several hours after hatching. Experimentally obtained results reveal that navigation is possible for baby mallards before the critical period of imprinting.

4. FEEDING-BASED NAVIGATION

4.1 Experiment setup

For this experiment, we conducted navigation experiments for adult mallards using feed and another UGV. Fig. 8 depicts the UGV (Blizzard FR1/12EP Belt Vehicle; Kyosho Corp.) after attaching a feed box (FB). The body is 488 mm long, 320 mm wide, and 220 mm high. We installed a water-protected monocular camera (CS-QR300; Planex Communications Inc.) at the UGV rear top. The image resolution was one million pixels.

Figure 9: Exterior (upper) and inside (lower) of the aviary.

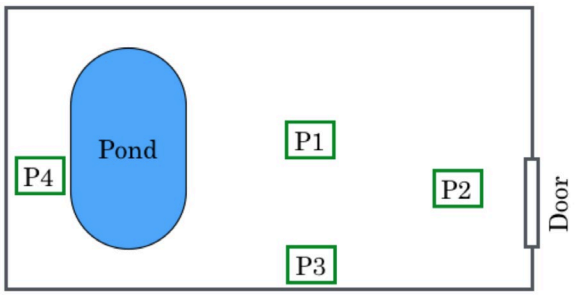

Figure 10: Layout and assignment of the UGV and FB.

4.2 Experiment results

For this experiment, we used nine adult mallards (six months old) without imprinting. We conducted feed learning experiments for them, not only getting used to the UGV while eating feed, but also following the UGV with a desire to get feed. To relieve wariness, we changed the ten experiment conditions in terms of positional combinations between the FB and the UGV, feed types, and sound stimulation. Mainly, we used compound feed that comprises corn, soybean, milo, bran, press cake, and fish flour. Table 1 denotes the experimental conditions including dates and hours.

For the first experiment, we placed the UGV and the FB at P1. We played a sound clip of calling recorded in advance using a microphone. Figure 11 depicts images obtained using the camera on the UGV. The mallards gathered at a corner in the aviary. They did not attempt to approach the UGV because they might have alerted. We observed that they seemed to watch the UGV while keeping their distance. As described herein, we gave no feed to the mallards from the morning of the experiment day. Although they were hungry, they did not approach the feed because of their own wariness. Compared with curious baby mallards, adult mallards were more vigilant against something that they saw first. We considered that the fear of natural enemies was attained by adult mallards for their work in paddy fields.

Table 1: Experiment conditions

No.	Date	Time	UGV	FB
1	Nov. 30th	13:00–14:00	P1	P1
2	Dec. 4th	11:00–13:00	P1	P1
3	Dec. 4th	13:00–13:20	P2	P1
4	Dec. 4th	13:20–13:30	P2	P3
5	Dec. 4th	13:30–13:40	–	P3
6	Dec. 4th	13:40–13:50	P4	P3
7	Dec. 12th	13:30–14:30	P3	P3
8	Dec. 14th	13:00–14:00	P3	P3

Figure 11: Behavior and response patterns for the first experiment.

One week later, we conducted the second experiment. We gave no feed to the mallards during the two days prior. The UGV and the FB were placed in a similar position with playing of a similar sound clip. As additional feed, we gave them cabbage and broccoli, which are vegetables preferred by mallards. The mallards gathered to a corner in the aviary. They showed no approach to the FB on the UGV. After a few minutes, we observed that their wariness had disappeared. Two mallards watched the UGV from the pond. However, they showed no approach to the UGV.

For the third experiment, the UGV position was changed to P2 near the entrance whereas the FB position remained at P1. We expected that mallards would eat the feed irrespective of wariness of the UGV because the UGV and FB were located separately. However, they did not approach the FB.

For the fourth experiment, the FB position was changed to P3, although the UGV position remained at P2. Moreover, we changed the feed to rice with small granularity. Mallards like to eat rice more than compound feed. However, they showed no approach to the rice.

For the fifth experiment, we removed the UGV, although the FB position remained at P3. Although the UGV did not exist in their view range, they exhibited no approach to the FB.

For the sixth experiment, we placed the UGV at P4 whereas the FB position remained at P3. During the previous five experiments, mallards frequently gathered P4 and its surrounding area. For this experiment, mallards gathered at a position between P3 and P4. Particularly, they moved near P3 when the UGV moved P4. However, they showed no feed eating.

The seventh experiment was conducted eight days after the sixth experiment. We set this period for mallards that became accustomed to the FB. The UGV and the FB were placed at P3. The one-hour observation result demonstrated that mallards showed no feed eating.

Before the eighth experiment, we left the UGV for two days in the aviary. The UGV and the FB were placed at P3, which was a similar position to that used in the previous experiment. As an experimentally obtained result, Fig. 12 depicts images obtained from the camera on the UGV. Mallards were swimming in the pond after relieving wariness, as depicted in the upper two images. Twenty minutes later, one mallard approached the UGV with feed, as depicted in the bottom two images of Fig. 12. Other mallards gathered around the UGV to eat the feed. We moved the UGV slightly while they were eating. They ran away immediately when the UGV moved. As described herein, they approached the UGV from rear. We considered that this behavior derived from a rapid escape response to a dangerous situation.

Figure 13: Breeder to give feed to ducks.

After stopping the UGV, we attempted to approach the mallards. Fifteen minutes later, another mallard approached. The mallard gradually shortened the distance to the FB. Other mallards were eating feed. We forwarded the UGV slightly again. Although the mallards fled all at once, the escape distance was shorter than that of the UGV movement. Apparently, the wariness was relieved for mallards. Although mallards approached from a large place behind, they gathered for eating feed from a narrow direction behind.

4.3 Discussion

Results obtained from eight experiments indicate that adult mallards had strong wariness. We demonstrated that at least two days are required to get used to the UGV and the FB. Moreover, they do not always eat feed. Maintaining navigation using feed alone is expected to be difficult because mallards eat feed only several times a day. As described herein, a breeder gave feed with similar behavior from a similar place every day, as depicted in Fig. 13. We infer that mallards recognize the input combined with breeder's behavior patterns. For this experiment, the FB was placed in the aviary with the feed placed in advance. We infer that the similar behavior to enter feed to a vacant FB on the UGV contributes to wariness relaxation for mallards. Moreover, we infer that the wariness for the UGV movements is relieved if they recognize it as a harmless object.

5. CONCLUSION

To actualize highly efficient rice-duck farming, this study presented experimentally obtained results to verify a useful method to navigate mallards using the UGV combined with imprinting and feeding. Experimentally obtained results revealed that baby mallards with imprinting followed the UGV. We considered that adult mallards require more than two days to become accustomed to the UGV and the

FB because they have strong wariness against unknown objects. Although we did not actualize mallard navigation, we found that mallards ate feed in the FB on the UGV. We confirmed the necessity of conducting imprinting during a baby term for mallard navigation.

As future work, we expect to quantify the imprinting effects of shared time between the UGV and mallards in a breeding process. Moreover, we expect to conduct a navigation experiment using feed of several types in a paddy field for baby mallards after imprinting.

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Oral Session | Others (including the category of JSAM and SASJ)
[4-1600-D] Other Categories (1)
Wed. Sep 4, 2019 4:00 PM - 6:15 PM Room D (4th room)

[4-1600-D-09] Onion Bulb Counting in a Large-scale Field Using a Drone with RTK-GNSS

*Satoshi Yamamoto[1], Hirokazu Madokoro[1], Yo Nishimura[1], Yukio Yaji[1] (1. Akita Prefectural University(Japan))

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Onion Bulb Counting in a Large-scale Field Using a Drone with RTK-GNSS

Satoshi Yamamoto[1*], Hirokazu Madokoro[2], Yo Nishimura[1], Yukio Yaji[1]

[1]Faculty of Bioresource Sciences, Akita Prefectural University, Japan
[2]Faculty of Systems of Science and Technology, Akita Prefectural University, Japan
*Corresponding author: syamamot@akita-pu.ac.jp

ABSTRACT

RTK-GNSS mounted on a drone made it possible that relatively accurate orthomosaic and digital elevation model (DEM) were generated with minimum number of ground control point (GCP) in a large-scale onion field. Deep learning was then applied to detect onion bulbs in the orthomosaic images. We annotated the bulbs of 16,812 with 250 images for the object detection. After machine learning process, the detection rate was 0.60 while the recall was 0.16. When the trained model was applied to the orthomosaic images, the number of the onion bulb ranged from 29,970 to 109,694 which were from 5 % to 19 % of the estimated onion plant number. Our next step would be to improve the trained model by reducing the false-negative value in the confusion matrix.

Keywords: onion bulb, growth measurement, drone, RTK-GNSS, orthomosaic, deep learning

1. INTRODUCTION

Onion (*Allium cepa L.*) is one of the staple vegetables in Japan. More than 60 % of onion is produced in Hokkaido, large northern islands of the country. Other main producing areas are in south part. In Japanese onion production, off-harvest season is in July and August. The market price is relatively high during the period. Ogata village is well known as a large-scale rice production area for more than 50 years. Recently, some farmers have started onion production in the region for more stable management because the harvest season of onion is from June to July in Akita prefecture. Monitoring crops throughout the vegetation period is essential to achieve higher yield and quality in onion production. However, it should be difficult to check the health of plants accurately in a large-scale field by human-eyes. Drone, which can move around all the field automatically, seems to be a useful tool to scout crops grown in large field. To construct accurate three-dimensional model of the field, many ground control points (GCPs) are necessary because the positioning sensor of a usual drone has an error ranging up to 10 m. It is tedious work to correct camera alignment referring GCPs by human eyes. Furthermore, it is difficult to set GCPs in the middle of agricultural field because it should be obstacles for a tractor and other farm machineries. If a drone can obtain accurate position information, it is thought that the number of GCP could be reduced dramatically. To generate accurate 3D model, LiDAR (Christiansen et al., 2017) and RTK-GNSS (Pix4D, 2017, Chen, 2017) have been researched. RTK-GNSS is a kind of position measuring device which brings extremely precise position information. Even if high precision orthomosaic of the onion field applying a drone with RTK-GNSS and least number of GCPs could be generated, it should be difficult to get valuable information without analyzing the orthomosaic in a stable manner. Deep learning seemed to be one of strong method to detect the target robustly.
In this study, our objective is to clarify how to conduct crop monitoring efficiently and accurately. Onion bulb counting was thought to be a suitable operation to test the developed monitoring system.

2. MATERIALS AND METHODS

2.1 Measurement system

A digital single lens reflex camera is ideal high-performance camera to obtain plant growth information from points of optical quality and data quantity. Figure 1 shows components of the measurement system. As a drone which can carry the heavy measuring equipment, we used Matrice 600Pro from DJI which can lift up weight of 2.6 kg and the typical flying time is about 30 minutes. A digital single lens reflex camera EOS 6D Mark II from Canon was mounted on a gimbal Ronin MX from DJI. The image size was 6240 x 4160. To capture an image by remote control, infrared light system was set in front of the sensor of the camera. The operator can check the image with iPad which is attached to remote controller because HDMI signal is sent from camera to iPad through the drone system. Basically, the camera and the drone doesn't communicate each other only sending one-way signal.

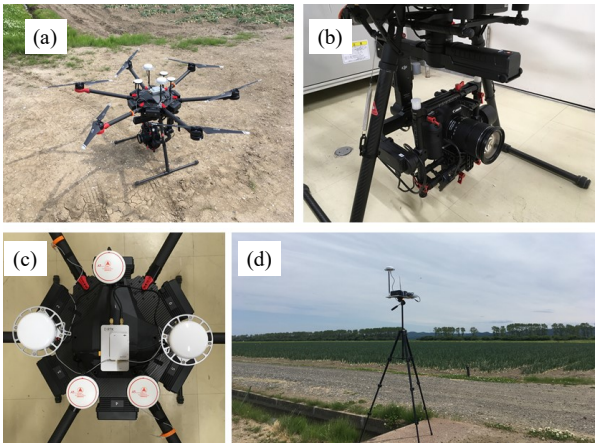

Figure 1. Drone components: (a) Matrice 600Pro from DJI. (b) a digital single lens reflex camera: EOS 6D Mark II from Canon, and a gimbal of Ronin MX from DJI. (c) two RTK-GNSS receivers and three redundant GNSS receivers. (d) a base station for RTK-GNSS .

The original drone has three redundant GNSS antennas to improve the robustness of position measurement. But the accuracy is approximately less than 10 m without correction signal from base station. RTK-GNSS brings positioning accuracy of less than 5 cm. Base station of RTK-GNSS is necessary to achieve the accuracy. Figure 2 shows trajectories of the drone.

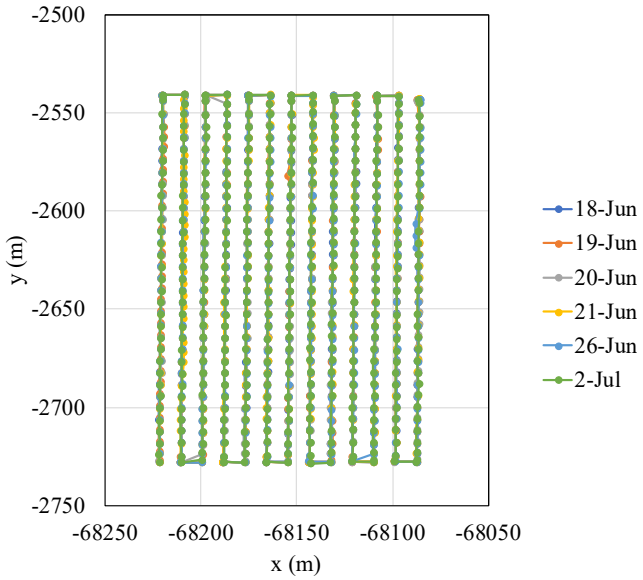

Figure 2. Flight trajectories on June 18th, 19th, 20th, 21st, 26th and July 2nd.

The data was recorded in drone memory during flights. In six flights, the routes are almost same when the RTK-GNSS receiver mode was fix. But the RTK data wasn't written to EXIF of the image because the camera and the drone weren't linked. If a drone stops when grab an image, the position data should be accurate. However, if the images are captured while the drone moves, the position data should have some errors. The camera had its own GNSS receiver, and the GNSS time was recorded to EXIF. According to the GNSS time of EXIF, nearest two of GNSS time of RTK data were selected, then position was calculated based on the data. They are processed with 3D reconstruction software Metashape from Agisoft. When images were grabbed in the large-scale onion field, the number of images was 386 to 430. In Metashape, workflow was as follows: loading photos into the software, aligning photos, building dense point cloud, building digital elevation model (DEM), building orthomosaic, and finally, exporting results. The resolution of the orthomosaic and DEM is about 7 mm/pix and 3 cm/pix respectively. As minimum preparation by hand, three GCPs were set for each data set.

2.2 Onion bulb detection

From the orthomosaic, onion bulbs are observed to be counted by image processing. To detect the onion bulb robustly, deep learning was then applied to generated orthomosaic images. For the machine learning, image size should be 320 x 192. So we separated the orthomosaic into approximately 9000 small images, then, 250 images are randomly selected, then we annotated the bulbs of 16,812 manually. Annotation is relatively easy because the onion bulbs were located in line as shown in figure 3. HALCON, image processing software, provides deep learning function with prepared as compact type using "object detection". The detection rate (TP/(TP+FP)) was 0.6, the recall (TP/(TP+FN)) was 0.16 with intersection over union (IoU) was 0.5. The field size was 2.4 ha; 135 m x 180 m. Four rows distance was 0.24 m, plant distance was 0.1 m, the number of plant bed was 107 rows in field width 180 m. The length of row was 132 m, the number of onion plants in the field was estimated to 564,960.

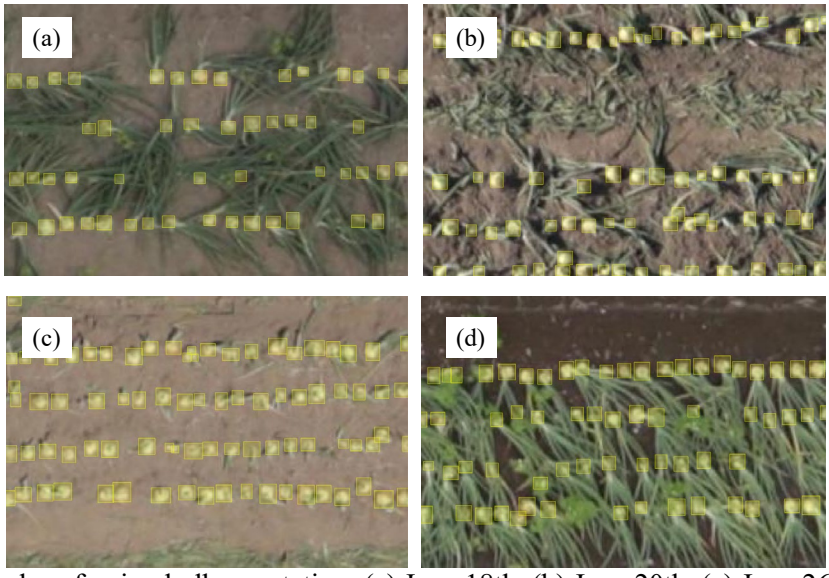

Figure 3. Examples of onion bulb annotation: (a) June 18th. (b) June 20th. (c) June 26th. (d) July 2nd.

3. RESULTS AND DISCUSSION

3.1 Orthomosaic

The series of orthomosaic and DEM are shown in figure 4 and figure 5. Obviously the DEM of June 20th, 26th and July 2nd have sphere shape error. This should be improved if the number of GCP increases while the manual process should be tedious. This is coursed by the wrong EXIF information of the camera. The camera was set just below the drone, the GPS condition wasn't good. It was revealed that some waiting period is necessary for stable GNSS signal condition for the camera. The rest DEM show similar land shape.

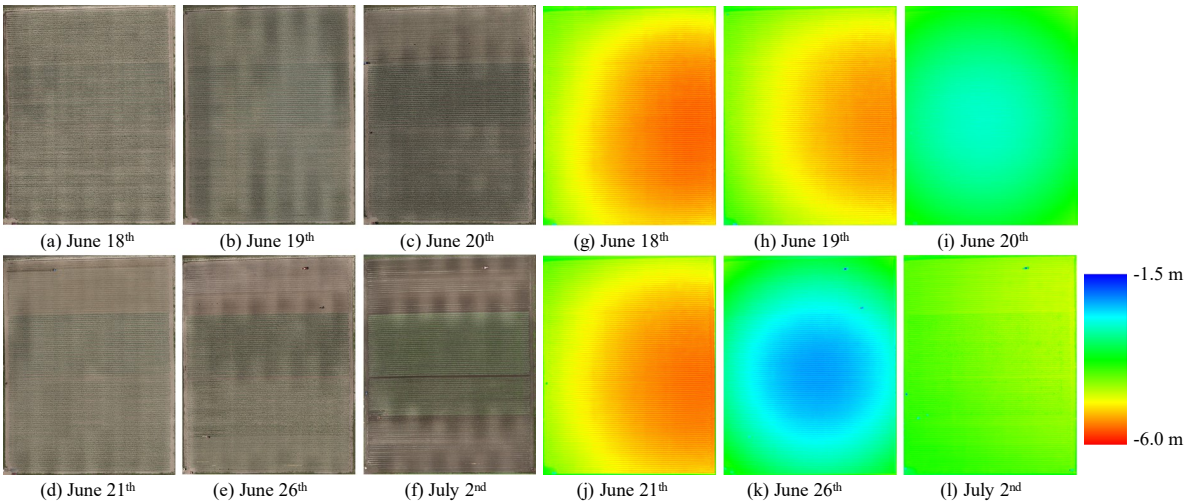

Figure 4 Orthomosaic and DEMs of onion field: (a) - (f) are orthomosaic images. (g) - (l) are DEMs.

Histograms of the altitude data of each pixel is shown in Figure 5. Deference between group of 18th, 19th and 20th and the rest is observed clearly. From above, if the GPS time in EXIF is correct, it is possible to obtain precise orthomosaic and DEM with only three GCPs.

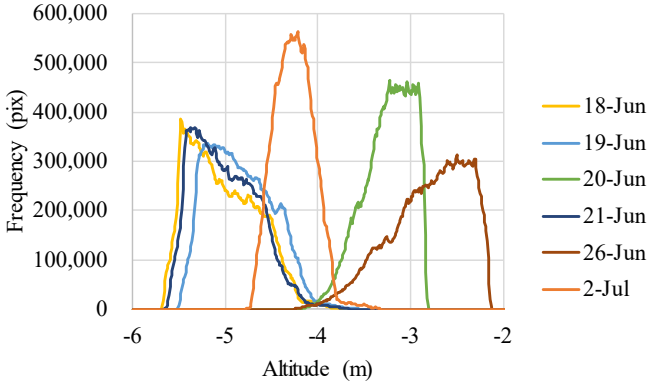

Figure 5 Histograms for each altitude data of DEM.

3.2 Onion bulb counting

The training image weren't sampled if the image didn't include onion bulb. As a result, number of false positive increased on grass area of neighboring the field. After detection of onion bulbs using deep learning, detected onion regions which is out of the field was eliminated. On June 26th and July 2nd, part of the field was empty after harvesting operation. The number and the estimated detection rate is shown in table 1. the number of the onion bulb ranged from 29,970 to 109,694 which were from 5 % to 19 % of the estimated onion plant number. As shown in figure 6, halves of bulbs weren't detected. It was revealed that the false-negative value in the confusion matrix should be reduced.

Table 1 Result of onion bulb counting.

Date	June 18	June 19	June 20	June 21	June 26	July 2
Onion bulb count	64,492	29,970	109,694	47,748	57,629	45,107
Row count	107	107	107	107	80	51
Plant count	564,960	564,960	564,960	564,960	422,400	269,280
Detection rate (%)	11	5	19	8	14	17

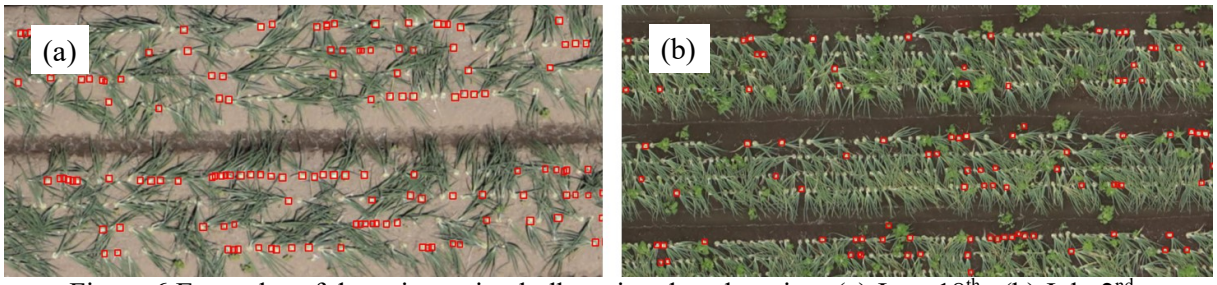

Figure 6 Examples of detecting onion bulbs using deep learning: (a) June 18th . (b) July 2nd .

4. CONCLUSION

We captured about 400 images of 6k resolution in a large-scale onion field using drone with RTK-GNSS. When the image localization was conducted successfully, precise orthomosaic and DEM were obtained with minimum number of GCPs. We then counted the number of onion bulbs applying deep learning for detection. The accuracy was low, however, our next step would be to improve the trained model by reducing the false-negative value in the confusion matrix.

ACKNOWLEDGMENT

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Poster Displaying

[Poster Session] Poster Displaying

Wed. Sep 4, 2019 11:30 AM - 12:30 PM Poster Place (Entrance Hall)

Posters need to be displayed until 12:30.