**APPENDIX D**

**SAES-422**

**Format for Multistate Research Activity**

**Accomplishments Report**

**Project/Activity Number**: **NC-1023**

**Project/Activity Title**: Engineering for Food Safety and Quality

**Period Covered**: October 2021 to September 2022

**Date of This Report**: December 9th, 2022

**Annual Meeting Date(s):** October 16-18th 2022

**Participants (29**): Youngsoo Lee, Efren Delgado, Qingyang Wang, Ashim Datta, Deepti Salvi, Mohammed Kamruzzaman, Kasiviswanathan Muthukumarappan, Kirk Dolan, Barbara Chamberlin, Ali Ubeyitogullari, Buddhi Lamsal, Roger Ruan, Jiajia Chen, Gail M. Bornhorst, Juliana M. Leite Nobrega de Moura Bell, Rohan V. Tikekar, Wenbo Liu, Pawan Takhar, Mukund Karwe, David S Jackson, Yi-Cheng Wang, Kiruba Krishnaswamy, VM Balasubramaniam, Paulo Silva, Ilce G. Medina-Meza, Fanbin Kong, Ozan Ciftci, Dharmendra Mishra.

**Brief summary of minutes of annual meeting**: The annual meeting was held at Urbana Champaign from Oct 16-18th, 2022. The opening dinner was held at the iHotel on October 17th and the meeting sessions started on Oct 18th at the University of Illinois. Dr. Takhar, one of the hosts, welcomed attendees and Dr. Ciftci introduced the meeting goals. Dr. Chen provided the Washington update describing the USDA strategic priorities, fiscal 2023-year budget, and the need to further deepen the definition of processed foods and educate the general population about the impact of processed foods on human health. Dr. Jackson revised the major milestones and outcomes for the project and provided guidelines to help report the progress accomplishments. Dr. Ciftci provided an overview of the specific activities proposed and accomplishments achieved. Each station provided a 5 min presentation describing their collaborations with other stations and areas seeking collaborations. Research accomplishments were provided for the project milestones. Dr. Bornhorst and Dr. Tikekar presented the USDA NIFA 2021 Partnership Award in Mission Integration of Research, Education, or Extension that was awarded for the NC 1023 multi-institutional seminar course and provided some statistics related to the offering of the course in 2021 and 2022. Stations interested in offering the course in 2023 were identified and an action plan was established to deliver the course. Ad hoc committees were revised, and chairs, co-chairs, members, and outcome activities were selected for each committee. UC Davis was selected to host the next meeting and Dr. Mishra was elected secretary. No changes happened in the steering committee composition. A pilot pant tour of the Food Science and Integrated Bioprocessing Research Laboratory was offered. Current problems in food engineering were discussed and groups were formed to identify strategies to contribute to the project objectives, resulting in several action plans for the groups. The meeting ended on noon on October 18th, 2022. Detailed minutes are available upon request.

**Accomplishments:**

1. Characterize physical, chemical, and biological properties of raw and processed foods, by-products, and packaging materials.

NE collaborated with MI station to characterize the physico-chemical properties of quinoa seed lipids extracted with supercritical carbon dioxide.

NE collaborated with OR, MI, WA, IN, VA, IA, and MS to determine the phenolic composition and the antioxidant properties of the grape pomace extract obtained by conventional and unconventional extraction methods.

AR, MN and IA collaborated on the development of food safety monitoring and prediction system for poultry and pork supply chains.

IN collaborated with MI to estimate the temperature-dependent thermal properties of food products in the range 20 - 140oC.

MS collaborated with UIUC, NCSU and LSU to quantify/model/measure quality characteristics for grading and sorting of sweet potatoes using optical technologies.

NJ collaborated with NC to evaluate the quality of sweet basil leaves that are grown hydroponically with plasma activated nutrient solution.

NJ collaborated and with Drexel University to evaluate the properties of plasma activated water and plasma activated nutrient solution.

GA collaborated with OR to measure dielectric properties of hazelnuts and determine their characteristics with Radio Frequency heating.

GA collaborated with ME to study surface modified cellulose nanocrystals for effective delivery of hydrophilic bioactive compounds in the gastrointestinal tract

TN collaborated with Oak Ridge National Laboratory to study the role of peptides in inhibiting ice crystal growth during frozen storage.

TN studied processes leading to (A) formation of novel food biopolymeric emulsifiers with improved emulsifying properties, (B) incorporation of bioactive compounds in foods, (C) food antimicrobial intervention strategies improving microbiological safety, and (D) novel food colloidal systems with enhanced physical properties

1. Develop advanced and sustainable processing and packaging technologies to transform raw materials into safe, high quality, health-promoting, and value-added foods.

CA collaborated with MD to develop synergistic processing technologies able to improve food quality and safety and reduce energy requirements.

IN collaborated with MI to design and build advance heaters for thermal properties measurement.

IN collaborated with WA, NE, MS, VA, OH, IA, MI, IA, OR on comparative study on extraction of phenolic compounds from grape pomace.

MS is collaborating with Dr. Lu, Dr. Zhang, and Dr. Chang to realize the automated fish processing operations.

IA collaborated with USDA/ ARS, Peoria, IL in improving functional aspects of plant protein ingredients.

MD collaborated with CA to develop ultrasound assisted antimicrobial treatments for improved food safety.

NC collaborated with NJ on the application of plasma-activated nutrition solution for enhancing the growth and yield of hydroponic basil.

NC collaborated with CA to develop a novel method for determining the dosimetry of plasma technologies.

NM collaborated with OH to analyze the effect of high-pressure treatment on the functional quality of cottonseed meal protein isolates.

GA collaborated with TX to study continuous high-pressure processing and quality parameters for pasteurization of grapefruit, watermelon, cantaloupe, and blueberry juices, as compared with high temperature short time process.

TN collaborated with AR and NE to develop an integrated radiofrequency and packaging technology in pasteurizing low moisture food products.

1. Develop mechanistic and data-driven mathematical models to enhance understanding and optimization of processes and products that will ensure sustainable and agile food manufacturing for safe, high quality, and health-promoting foods.

CA collaborated with NC to develop data-driven model for dosimetry of non- thermal plasma.

IL collaborated with WA to combine microwave heating with conventional heating to develop fryers allowing improved control over pressure development and oil uptake in foods.

IL collaborated with PA to perform CFD and FEM modeling of a commercial food slicer to improve sanitization and reduce cold spots.

Il collaborated with MI to develop data-driven optical sensing technology for sweet potato based on physical properties and other quality attributes.

IN is collaborating with AR to develop machine learning models to investigate different soybean varieties and their properties.

GA collaborated with TN station to model Radio Frequency heating of low moisture foods surrounded with different media

MD collaborated with CA to develop a better understanding of the food matrix effect on survival and virulence of *Salmonella*

NJ collaborated with CA to develop a system to test the effect of shear stress on leafy fresh produce surface for bacterial detachment and with NC to develop systems for applications of plasma activated water in sprouts and plasma activated mist in fresh produce

OH collaborated with NY to elucidate the mechanisms of contamination and infiltration into spinach leaves during vacuum cooling and validate a CFD model describing temperature and relative humidity distribution during superheated steam treatment in a simulated food processing environment.

TN collaborated with TX to model the drying process of sausages.

1. Adapt pedagogical strategies involving novel educational approaches to enhance and assess student learning of food engineering.

MD, CA, and NE led the 2022 NC1023 Food Engineering Seminar Series, which provided a broad perspective of innovative topics in Food Engineering (e.g., thermal processing, nonthermal processing, and sensing). Ten universities (New Mexico State University, University of Arkansas, North Carolina, UC Davis, Maryland, University of Illinois, Utah State University, Purdue University, Michigan State University, Ohio State University) contributed to this effort, which resulted in live attendance of 44-86 people, ~13.5 h of videos, >432 hours of video viewed. Moderate Q&A and interaction time were included after each presentation.

IA collaborated in the Higher education challenge (HEC) grant, led by UMaine, where 6 universities participated (KY, ME, IA, VA, WA, ID). This effort focused on Enhancing Learning Outcomes in Food Engineering and Processing Courses for Non-Engineers Using Student-Centered Approaches and Implementing a few active learning tools. Its impact was evaluated through student surveys. CA collaborated with MD station in the development of teaching modules for food processing using virtual realities.

NMSU recently completed the innovativemedia.nmsu.edu (Sanitization online learning modules (pre- and post-harvest) and Animations describing different concepts and processes) and is currently developing Virtual Reality for microbiomes, and internship prep, Game for understanding complexity of water use issues, and Game for regulation of safety requirements for farmers markets.

The Conference of Food Engineering 2022 was held in Raleigh, NC from September 18-21, 2022, and involved multiple stations.

TN worked on a USDA Research and Extension Experiences for Undergraduates (REEU) program on training more food engineers to advance food processing in the food industry

**Impacts:**

1. Developed new mechanistic models to understand various processes critical for food safety, processing and quality
2. Initiated a multi-institutional research program to evaluate physical properties of foods.
3. Developed and optimized several new technologies (e.g. light, high pressure, cold plasma, pulsed electric field, ultrasound, high-pressure processing, and microwave and other thermal processes) to enhance the safety of various food products
4. Invented, designed and developed new devices to measure engineering properties of foods.
5. Several new pedagogical techniques were formulated and implemented to enhance student learning of food safety and engineering principles

**Publications:** A complete list of research publications from NC-1023 members is available upon request. Here, we highlight publications that resulted from collaborative activities between members.

1. Cui H., Wang Q., Raw R., Salvi D., Nitin N. DNA-based surrogates for the validation of microbial inactivation using cold atmospheric pressure plasma and plasma-activated water processing. Journal of Food Engineering, 339 (20223) 111267.
2. Benyathiear P., Dolan K.D., and Mishra D. K. “Optimal Design of Complementary Experiments for Parameter Estimation at Elevated Temperature of Food Processing.” Foods 2022, 11, 26
3. Tan J and Karwe MV. 2021. Inactivation of Enterobacter aerogenes on the Surfaces of Fresh-cut Purple Lettuce, Kale, and Baby Spinach Leaves using Plasma Activated Mist (PAM). Innovative Food Science and Emerging Technologies, 74: 102868.
4. Tan J, Zhou B, Luo Y., and Karwe MV. Numerical Simulation and Experimental Validation of Bacterial Detachment using a Spherical Produce Model in an Industrial-scale Flume Washer. Food Control, Vol. 130: 108300.
5. Tan J and Karwe MV. 2021. Inactivation and Removal of Enterobacter aerogenes Biofilm in a Model Piping System using Plasma-activated Water (PAW). Innovative Food Science and Emerging Technologies, 69: 102664.
6. Wang, Q., Pal, R. K., Yen, H. W., Naik, S. P., Orzeszko, M. K., Mazzeo, A., & Salvi, D. (2022). Cold plasma from flexible and conformable paper-based electrodes for fresh produce sanitation: Evaluation of microbial inactivation and quality changes. Food Control, 108915.
7. Wang, Q., Cui, H., Salvi, D., & Nitin, N. (2022) DNA-based Surrogates for Validation of the Microbial Inactivation Process for using Cold Atmospheric Pressure Plasma (CAPP) and Plasma-activated Water (PAW) processing. Journal of Food Engineering. Volume 339, February 2023, 111267.
8. Rivero, W., Wang, Q., & Salvi, D. (2022) Effect of Plasma-activated Water on Microbiological and Quality Characteristics of Alfalfa Sprouts, Broccoli Sprouts, and Clover Sprouts. Innovative Food Science & Emerging Technologies. Volume 81, 103123 4.
9. Salvi, D. and M.V. Karwe (2021) Sustainable and safer indoor farming of produce using new technologies: challenges and opportunities. The International Union of Food Science and Technology (IUFoST), Scientific Information Bulletin (SIB). http://www.iufost.org/news/urban-foodproduction- new-sib.
10. Pyatkovskyy, T., Ranjbaran, M., Datta, A.K., and Sastry, S.K. 2021. Factors affecting contamination and infiltration of Escherichia coli K12 into spinach leaves during vacuum cooling. J. Food Engineering 311:110735. https://doi.org/10.1016/j.jfoodeng.2021.110735
11. Mok, J.H, Niu, Y, Yousef, A.E., Zhao, Y., and Sastry, S.K. 2022. Spatial persistence of Escherichia coli O157:H7 flowing on micropatterned structures inspired by stomata and microgrooves of leafy greens. Innovative Food Science and Emerging Technologies 75: 102889. <https://doi.org/10.1016/j.ifset.2021.102889>
12. Mok, J.H, Niu, Y, Yousef, A.E., Zhao, Y., and Sastry, S.K. 2022. A microfluidic approach for studying microcolonization of Escherichia coli O157:H7 on leaf trichome-mimicking surfaces under fluid shear stress. Biotechnology and Bioengineering 119:1556-1566, <https://doi.org/10.1002/bit.28057>
13. Huu C. N.; Tikekar R. Nitin N. (2022). Combination of high-frequency ultrasound with propyl gallate for enhancing inactivation of bacteria in water and apple juice. Innovative Food Science and Emerging Technologies. 82, 103149.
14. Yi J; Lungu B.; Fletcher A.; Patra D.; Tikekar R.; Nitin N.; Simmons C.; Using virtual food processing environments to promote experiential learning. Journal of Engineering Education, in review.
15. Zhao, Y., Kumar, P.K., Sablani, S. S., Takhar, P.S. Hybrid mixture theory-based modeling of transport of fluids, species, and heat in food biopolymers subjected to freeze–thaw. Journal of Food Science 87(9):4082-4106.
16. Zhou, X., Zhang, S., Tang, Z., Tang, J., Takhar, P.S. Microwave frying and post-frying of French fries. Food Research International, 159, 111663: 1-11. 3) Lele, S.R., P.S. Takhar, and R.C. Anantheswaran, Modeling heat transfer during hot water sanitization of a commercial mushroom slicer. Journal of Food Process Engineering, 2022, 45(4): 1-13

**Conference Presentations:**

1. Farmanfarmaee A, Dag D, Zhao Y, Kong F. The dielectric properties of ground hazelnut kernels, shells and their mixtures at different frequencies, temperatures and moisture levels. 2022 IFT meeting. July 10 – 13, 2022.

2. Chen Q, Dag D, Kong F, Chen J. Modeling the Effect of Immersion Fluids on Radio Frequency Heating Performance of Corn Flour. 2022 IFT meeting. July 10 – 13, 2022. 25. Qin Z, Kong F. Development of Nanocellulose Incorporated Oleogel Matrix for the Encapsulation and Colon-targeted Delivery of the 5-aminosalicylic Acid. 2022 IFT meeting. July 10 – 13, 2022.

3. Zhou, X., Tang, Z., Takhar, P.S, Tang, J., Microwave-assisted frying and post-frying of French fries, 56th Annual Microwave Power Symposium (IMPI 56), Savannah, GA, June 2022, poster presentation.

4. Zhou, X., Zhang, S., Tang, Z., Takhar, P.S., Tang, J., Microwave frying and post-frying for oil reduction of French fries, The 4th Global Congress on Microwave Energy Applications (4GCMEA), Chengdu, China, August 2022, oral presentation.

**Collaborative grants:**

1. USDA Higher Education Challenge Grant project between UK, UMaine, Iowa, Virginia Tech, WSU, UIdaho is in its final year, and we are wrapping up activities.
2. D. Salvi, L. Johnson, N. Nitin (2022) USDA NIFA AFRI A1332 Dosimetry enabled applications of cold plasma technologies for the inactivation of biofilms on food contact surfaces
3. NIFA grant between Georgia and Texas for juice processing
4. NIFA funds for Nanocellulose digestion & Safety with Georgia, Maine and Missouri
5. RF heating with Georgia and Oregon
6. Tennessee stations submitted two USDA proposals collaborated with Arkansas, Nebraska, and Texas stations.
7. Utah submitted a proposal with Dr. Juzhong Tan to USDA-NIFA which is under review.
8. USDA NIFA 2020-70003-32301 (ongoing)
9. USDA-SCRI- Project titled Advancing American Elderberry into Mainstream Production and Processing