INTENSE PULSED LIGHT
FOR POWDERED FOOD PASTEURIZATION
WORKSHOP

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IPL FOOD SAFETY

CFANS
COLLEGE OF FOOD, AGRICULTURAL AND NATURAL RESOURCE SCIENCES

INTENSE PULSED LIGHT FOR FOOD SAFETY

Background

Particulate foods including seeds and powder are broadly used as the ingredients in manufacturing processed foods or consumed directly by humans and animals because of their convenience, versatility, and relatively long shelf-life.

http://www.scapewellbeing.com

https://www.bakersauthority.com/

https://www.walmart.com

https://www.planetnatural.com/

https://www.123rf.com/photo_96323137

https://www.epicurious.com

https://www.bonappetit.com/recipe/pantry-pasta-new

Selective foodborne outbreaks of particulate foods

Year	Food matrix	Brands	Pathogens	Reference
2016-2017	Milk powder	Valley Milk, TreeHouse Foods, New Hope Mills, Old Dutch Foods, Lactalis etc.	*Salmonella*, *Cronobacter sakazakii*, *Listeria monocytogenes*, Thermophilic *Bacillus* etc.	CDC 2012， 2016 & 2017, The Straits Times
2016 & 2019	Flour and flour products	General Mills, Molly & Drew, Continental Mills, Kerry Inc, etc	*Escherichia coli* O121, *Escherichia coli* O26, etc.	CDC 2016 & 2019
2018	Whey powder	Associated Milk Producers Inc., Mondelēz Global LLC, Pepperidge Farm, Flowers Foods, etc.	*Salmonella*, etc.	FDA 2018
2018	Sunflower seeds	Hudson Valley Foods, Inc. and Bhu Foods, etc.	*Listeria monocytogenes*, *E. coli* O157:H7, etc.	CDC & FDA 2018
2017	Almond	GoMacro, Hampton Farms, and NOW Health Group Inc., etc.	*Listeria monocytogenes*, etc.	CDC & FDA 2017

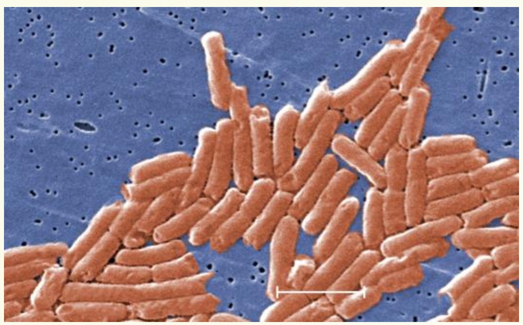
Routes of infection for particulate foods

Control the source of material

Apply effective sterilization process

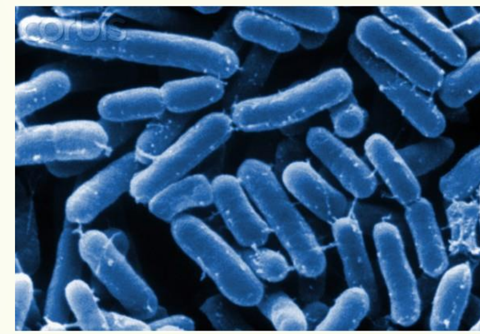
Control the processing areas

Control of points



https://www.foodengineeringmag.com

Pathogen contamination



http://www.dongnamlab.com/cronobacter-sakazakii-322

Source of pathogens

Raw ingredients

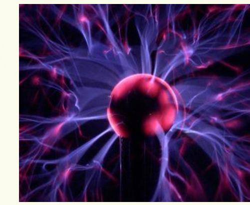
External environment (e.g. pests, water, and air)

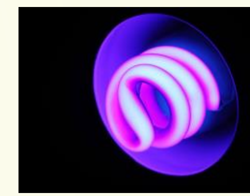
Inadequate hygienic and sanitation practices

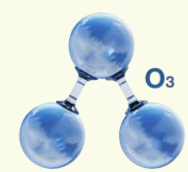
Lack of processing control

Nonthermal technologies used to eliminate pathogens in particulate food

Food product	Non-thermal pasteurization methods	Microorganism inactivation effect	Disadvantages
Powdered infant formula	Pulsed electric field	1.22 $\log_{10}$ CFU/g reduction of *C. sakazakii*	Low disinfection, difficult to control
Powdered infant formula	20 min ultraviolet radiation combined with hot water treatment	~3 $\log_{10}$ CFU/g reduction of *C. sakazakii*	Heavy oxidation, long treatment time
Liquid infant formula	600 MPa hydrostatic pressure processing	3.11 $\log_{10}$ CFU/g reduction of *C. sakazakii*	Not feasible for powdered food sterilization
Skim milk powder	90 min with 5.3 mg/L gaseous ozone	3.28 $\log_{10}$ CFU/g reduction of *C. sakazakii*	Not efficient and rapid for powdered food sterilization







Pina-Perez et al., 2007; Liu et al., 2012; Gonzalez et al., 2006; Torlak et al., 2013

Need for R&D

- Need for non-thermal pasteurization of powdered foods
- Advantages of the proposed technology
  - Less chemical (e.g. oxidative) and physical (e.g. thermal) damages to foods
  - Releases high peak power distribution during a pulse (as high as 35 MW compared with 100 to 1,000 W for continuous UV light)
  - Greater penetration depth than continuous UV light
  - Does not leave residual compounds or use external chemicals disinfectants and preservatives
  - Low selectivity on bacteria, spores and virus

Need for R&D

- Challenges to be addressed
  - Decontamination of powdered foods such as milk powder, egg powder, spices, and powdered beverages has not been well demonstrated
  - Engineering solutions are needed to remove several limitations of the technology. These limitations include powder agglomeration and caking and water activity changes during continuous treatment, explosion hazard, non-uniform exposure, etc.
  - How process and sample variables affect the performance of the process are not well understood
  - The effects of the process on nutritional value and quality, and the cost and benefit concerns with implementation of the technology in new plants and retrofitting in existing plants are not well understood
  - Development and realization of commercial scale continuous process equipment are yet to be accomplished

Project goal and objectives

- The goal of the project is to develop an intense pulsed light (IPL)-based technology for non-thermal pasteurization of powdered foods.
- The supporting objectives are: (1) to develop and construct an experimental continuous IPL apparatus; (2) to understand the contributions of variables to the performance of IPL process in terms of bactericidal effects and shelf-life stability; (3) to evaluate the effects of IPL process on nutritional values and sensory quality; (4) to optimize the process and develop a prototype system for field demonstration; (5) to introduce the technology and educate interested industrial users about the advantages of using IPL to ensure safer dry foods through extension efforts.

Project team – PD and co-PIs

- Dr. Roger Ruan – PD and PI, Professor, Director, Center for Biorefining, Department of Bioproducts and Biosystems Engineering and Department of Food Science and Nutrition, U of MN
- Dr. David Baumler – Co-PI, Assistant Professor of Molecular Food Safety Microbiology, U of MN
- Dr. Chi Chen – Co-PI, Associate Professor, Department of Food Science and Nutrition, U of MN
- Dr. Paul Chen – Co-PI, Research Associate Professor, Program Director, Center for Biorefining, Department of Bioproducts and Biosystems Engineering, U of MN
- Dr. Zata Vickers – Co-PI, Professor, Department of Food Science and Nutrition, U of MN
- Dr. Joellen Feirtag – Co-PI, Associate Professor and Food Safety Specialist, Department of Food Science and Nutrition, U of MN
- Dr. Laurence Lee – Co-PI, President, LZL Engineering

Project Advisory Council

- Dr. Tom Yang, US Army Natick Soldier Research, Development and Engineering Center, AFC
- Judy Fraser-Heaps, Land O'Lakes
- Gordon Kivi, KTCS, Inc.
- Cheryl Bell, Midwest Dairy Association
- Todd Jensen, General Mills
- John Snyder, Minnesga Inc.
- Dr. Laurence Lee – President, LZL Engineering

Project team – key participants

- Dr. Yanling Cheng, Research associate, BBE
- Dr. Peng Peng, Post-doctoral research associate, BBE
- Dr. Erik Anderson, Postdoctoral Researcher, BBE
- Dongjie Chen , Graduate research assistant, BBE
- Justin Wiertzema , Graduate research assistant, FScN
- Juer Liu, Graduate research assistant, BBE
- Qingqing Mao, Graduate research assistant, BBE
- Ashley Briones, Graduate research assistant, FScN
- Nina Le, Graduate research assistant, FScN
- Charles Schiappacasse, Graduate research assistant, BBE
- Nan Zhou, Graduate research assistant, BBE
- Myungwoo Kang, Graduate research assistant, FScN
- Shruthi Murthy, Graduate research assistant, FScN

Prototype/demo system

- Desirable dispersion mechanism
- Light source with optimal power specifications and arrangement
- CIP integrated
- Treated product outlet with maximum portability for easy implementation in final packaging station on existing production lines, and
- Compact mobile system suitable for field trials and demonstration.

Example Foods to be tested

- Milk powder
- Protein powder
- Infant formula
- Powdered egg
- Spices
- Flour
- Seeds

Evaluation

- Microbial inactivation
- Physical properties
- Chemical and nutritional properties
- Sensory quality

Key accomplishments of the project

Aiming at developing a technology for decontaminating powdered foods and ensuring their safety, the project team conducted rigorous research to develop and understand the intense pulsed light (IPL) technology as an alternative to conventional thermal and other novel non-thermal processes for inactivation of pathogenic microbes in powdered and particulate foods. The project began in February 2016. The 4-year project has been extended to 5+ years at no additional cost. The extended period was requested for the team to explore the potential applications of the intense pulsed light (IPL) technology. The key accomplishments of the project are:

- In the first year, we successfully developed and constructed a continuous IPL system which was subsequently used for a wide range of experiments that followed in the next two years. This accomplishment ensured that our researchers had the necessary processing capability to treat samples under different conditions including energy level, residence time, temperature, and RH, etc. In the later part of third year and fourth year, we redesigned the system based on our experience with the first system and experimental data and were able to construct upgraded versions of IPL systems. The latest system also incorporates the photocatalysis with the IPL and enables us to control treatment environments and continuous one-pass process in a much more effective and efficient manner.
- Our team developed and compared several bacteria inoculation protocols for powdered foods. Validated methods were subsequently used for all the experiments conducted in the project.
- We conducted a series of experiments to evaluate the bactericidal effects of IPL treatments of numerous powdered samples under different processing conditions. Process improvement and optimization and system development led to bacterial reduction of over 5 logs. We also conducted research to shed lights on the bactericidal mechanisms of IPL treatment using multiple techniques such as molecular biology, microscopy, high resolution NMR, chemometrics, and metabolomic analysis.
- Instrumental and sensory evaluation of the quality of the treated products was carried out. Physical and chemical changes were characterized and quantified. Sensory attributes were also quantified and related to instrumentally measured parameters.
- We interacted with the industry through annual industry advisory committee meetings, workshop in industry setting, testing samples provided by interested companies, and discussion on potential implementation of the technology in current production facilities.
- Over the past 4+ years, we showcased the technology and facility to the stakeholders through onsite tours, workshops, and conferences. Scientific findings were also published on peer reviewed journals.

Performance metrics of the project

- Research/students trained: 13 +
- Theses completed: 4
- Peer reviewed articles: 8
- Presentations: 45+
- Demonstrations: 10+
- Website: https://iplforfoodsafety.cfans.umn.edu/
- Curricula: 3
- Leverage external funding: $450 K+

What you can expect from this workshop

- We will share our knowledge with you who may be working in the food industry, particularly those in the powdered food sectors, or faculty who may be interested in expanding your research into this area, or graduate students who are looking for research ideas.
- The workshop combines lectures and virtual demonstrations.
- You will learn about the basic principles of IPL process, structure of an IPL system, key process parameters, operation procedures, and process and quality control.
- You will also learn most recent progress in research in the field through case studies.
- We hope this will stimulate more R&D efforts into this technology, help establish some research collaboration, and form industry partnership to implement the technology.

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USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

Thank you!

Questions?

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