PreScouter

Extending Shelf Life: Food Treatment Methods

Research Support Service

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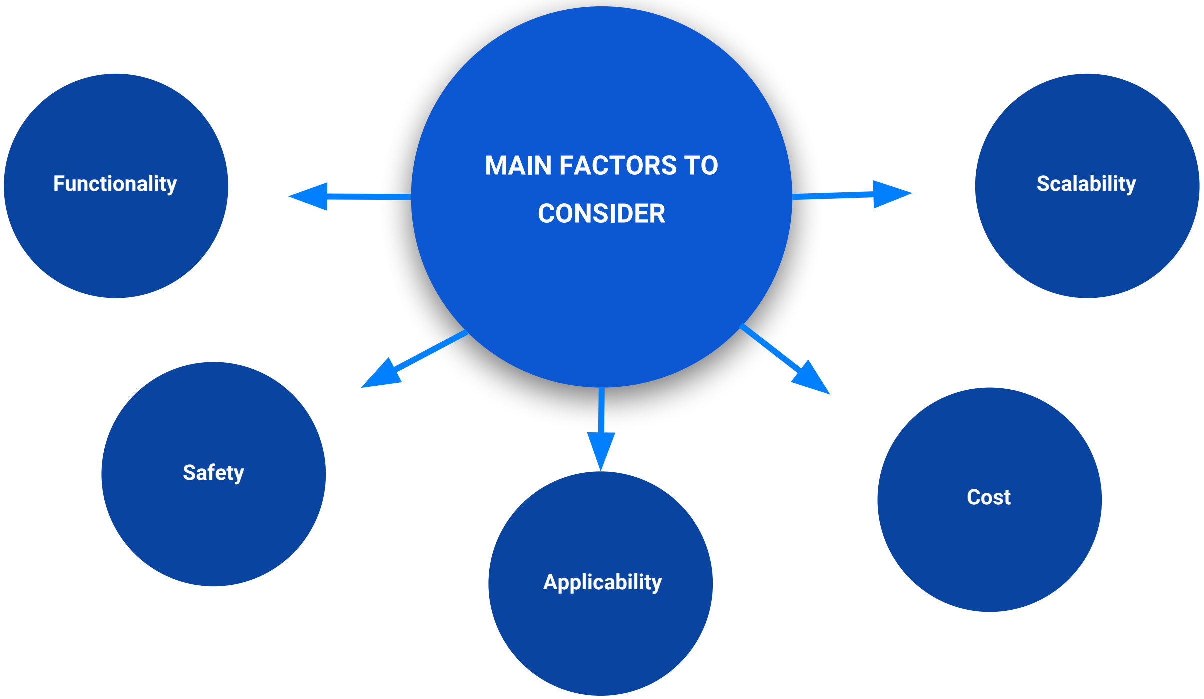
PRESCOUTER

Intelligence Brief Question

What are some of the newest food treatment methods currently in development for extending the shelf life of food and beverages throughout the industry?



Executive Summary

PreScouter Approach:

In previous reports, the PreScouter team focused on extending food and beverage shelf life by making changes to the packaging or including novel additives within the food substance. Another distinct avenue of focus is by treating the food (primarily on its surface) to help prevent decay mechanisms from occurring.

Developments currently within late research phases were of highest interest, and particular preference was given to treatments already approved for use in food and beverages.

Key Findings:

- Most of the treatments mentioned within this intelligence brief strive to remove or neutralize microbes on/within food prior to being packaged. With far fewer active microbes packaged with the food prior to being sold, researchers have seen a significant reduction in spoilage mechanisms and an overall improvement in shelf life stability.

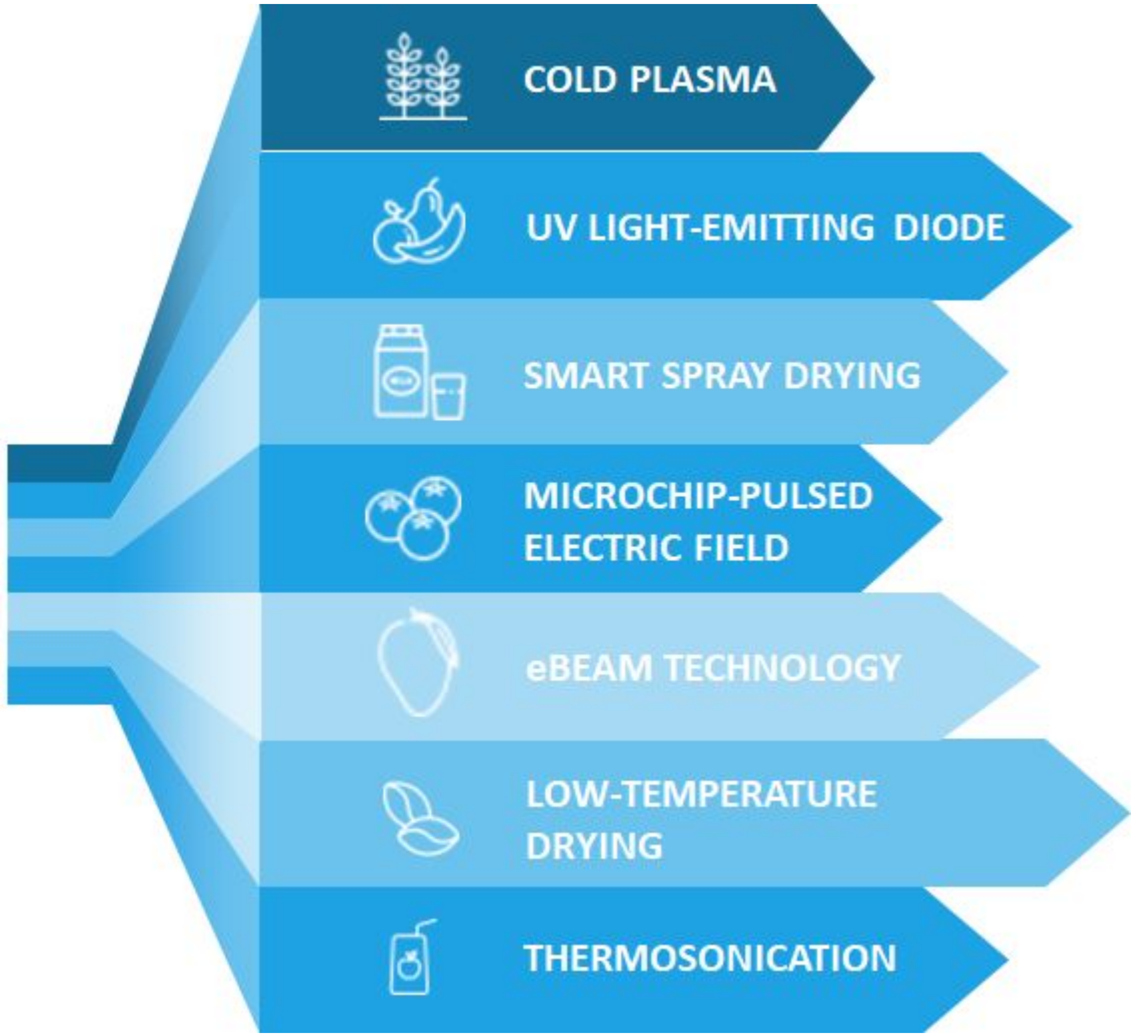
Executive Summary

- Many considerations must be included when selecting treatment methods to pursue within the food and beverage industry. As indicated in the Intelligence Brief question, these can include scalability, commercialization, safety, functionality, etc.
- Some of the techniques outlined will be fairly easy to commercialize - like UV light treatments, pulsed electric fields, etc; whereas other techniques like thermosonication are typically done in smaller batches and would require fairly high development costs to scale up.
- Functionality or modification of the food product is perhaps the most significant concern: if the food is changed by the treatment process beyond just extension of its shelf life, the product is no longer as viable. This may include changes to taste/flavor, color, pH, and more. Of particular focus would be whether or not the treatment method utilizes heat, as this type of process is perhaps most likely to change the product/environment significantly.

Technologies Included in Report

Extending Shelf Life

Food Treatment Methods



The Major Features of Each Technology

Technology	Company / Organization	Phase	Thermal	Effect on Functionality	Year	Page
Cold Plasma	Murdoch University; Iowa State University	Research	✗	✓	2017/2018	7
UV Light-Emitting Diodes	Agriculture and Agri-Food Canada	Prototype	✗	✗	2018	11
Smart Spray Drying	MONASH University	Prototype	✓	✗	2018	16
Microchip-Pulsed Electric Field	Beijing Forestry University 1952	Research	✗	✓	2018	20
eBeam Technology	A&M	Prototype	✗	✗	2017	24
Low-Temperature Drying	University of Nottingham UK | CHINA | MALAYSIA	Research	✓	✗	2018	29
Thermosonication	Jiangnan University	Research	✓	?	2017	33

Food Treatment Methods

Cold Plasma

Background

Cold plasma (CP) is a mixture of atoms, ions, and excited molecules at any temperature in the range of 25-450°C. CP is generated by applying electric current to a mixture of gases such as argon, nitrogen, or air. Both the medical and dentistry industries use CP as a disinfectant because it eliminates fungi and bacterial growth from surfaces. Two papers from Murdoch University and Iowa State University reviewed the potential of the CP technology for postharvest disease control (especially fungal growth) and its effect on food quality, respectively.

At a glance

Type: Dry, non-thermal process

Current Application: Medical and dental industry

Key Feature: Elimination of fungal and bacterial growth on surfaces

Applicability: Produce, grains, poultry

Year: 2017/2018

Main Limitation: Can physically damage delicate foods

Cold Plasma

Technology

In the food industry, the CP used is generated mainly from air with other noble gases added in at room temperature and pressure, which makes it chemically safe for direct contact with food. Three different methods are available for treating food with CP:

- **Direct:** The food sample acts as the second electrode needed to generate CP, bringing the sample into direct contact with the plasma
- **Indirect:** The plasma is generated in a closed circuit and then discharged as a jet onto the food sample
- **Hybrid:** The food sample acts as the second electrode, but a ground electrode is added to lower direct exposure of electric current to the food

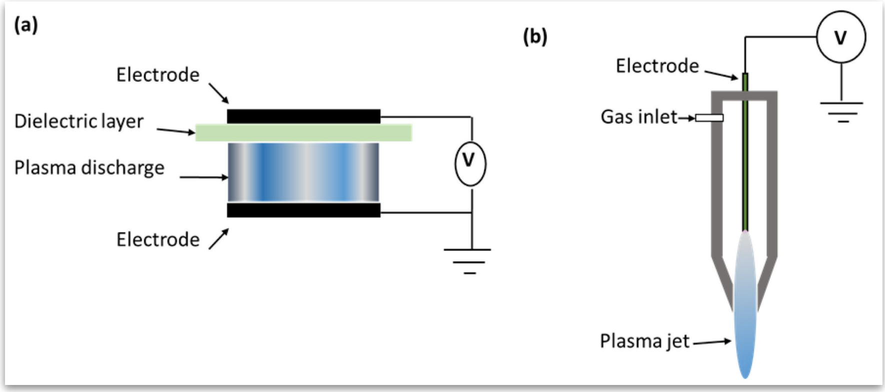


Figure: Schematic diagram of (**a**) dielectric barrier discharge; (**b**) plasma jet system.

Cold Plasma

Benefits

- It has been shown to be effective at stopping fungus germination at low temperature
- It leaves no residues on the food itself
- It produces no waste
- Feed costs are low since the only feed needed is air

Drawbacks

- Due to its high flow rate, plasma may physically damage delicate foods
- Possible loss of color at prolonged treatment times
- Especially in liquid food products, pH change has been observed
- The process by which CP stops germination is still not understood

Conclusion

Since this technology is still in the research stage, most experiments conducted have been in controlled laboratory environments and not in actual food packaging facilities. More test cases in facilities under various air conditions need to be conducted to gauge the effectiveness of this treatment in different regions of the world.

Further research is also needed to determine the effect of CP on the physicochemical properties (such as pH, acidity, proteins, enzymes, vitamins, and lipids) and sensory properties at the molecular level.

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UV Light-Emitting Diodes (LEDs)

Agriculture and Agri-Food Canada

Background

UV-C radiation is a nonionizing radiation and serves as a promising sanitizing technology for food, especially fresh-cut products. UV-C offers several advantages: no residue, no legal restrictions, easy to use, and no requirement for extensive safety equipment to be implemented. Agriculture and Agri-Food Canada (AAFC) is researching the efficacy of 277-nm UV LEDs for the inactivation of certain foodborne pathogens and mold spores on the surfaces of romaine lettuce and apples.

At a glance

Type: Superficial, non-ionizing radiation

Current Application: Air & water disinfection

Key Feature: Damage microbial DNA, inhibiting proliferation

Applicability: Produce

Year: 2018

Main Limitation: Relatively short lifespan of LED lamps compared to mercury ones.

UV Light-Emitting Diodes (LEDs)

Agriculture and Agri-Food Canada

Technology

UV-C light has a wavelength range of 200-280 nm and has been found to be effective at inactivating common food pathogens because this wavelength range aligns with the absorbance of DNA (at 260 nm). UV LEDs can be incorporated in various types of machines, from conveyor belts to chiller units. Since LEDs are more effective in colder temperatures, they lend themselves particularly well to use in chiller units and refrigerators. Many food items, including dairy and fruits, are already being processed with UV light.

Separate tests have been conducted where UV LEDs are installed in a refrigerator unit to observe their effect on strawberries and papayas. The LEDs were able to keep both fruits mold-free longer than fruits without UV exposure without significantly changing the physicochemical composition of either fruit.

Figure: The compact size of UV-C LED provides versatile options.

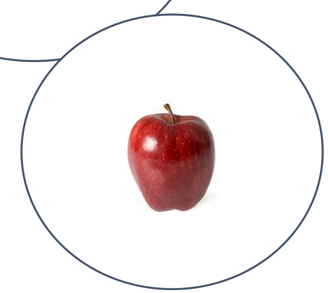
UV Light-Emitting Diodes (LEDs)

Agriculture and
Agri-Food Canada

Technology

The AAFC is currently investigating the efficacy of UV-C LEDs (λ=277 nm) for the inactivation of the foodborne pathogens *E. coli* O157:H7 and *L. monocytogenes* and mold spores on the surfaces of **romaine lettuce** and **apples**. Initial examination of the antimicrobial efficacy and power outputs of various wavelengths of UV LEDs, UV-C LEDs in the range of 275–280 nm were found to have the optimal trade-off between cost, lifetime, germicidal efficacy, and power output.

Figure: An example of a UV disinfection box that allows treating whole fresh produce samples



UV Light-Emitting Diodes (LEDs)

Agriculture and Agri-Food Canada

Benefits

- UV-C LED doesn't require heat or chemicals to disinfect food
- LED lamps do not contain the toxic chemical mercury, which makes it safer than traditional mercury lamps
- LED lamps can be used in cold environments
- LED lamps can emit a variety of wavelengths, which allows the tuning of the wavelength these LED lamps emit to match the wavelength of specific microbes for maximum effectiveness
- LED lamps are smaller in size, which allows for more variety in disinfectant equipment designs

Drawbacks

- The current lifetime of LED lamps (10,000 hours) is still much shorter than the lifetime of mercury lamps (12-18,000 hours)
- LED lamps are sensitive to high temperature and humidity
- LED lamps can overheat, further reducing their lifetimes

Conclusion

UV LEDs present a potential solution for the control of food pathogens and extension of shelf life throughout the supply chain. The main issues with UV LEDs is their shorter lifetime compared to currently used mercury lamps and the drop in power output when wavelengths less than 265 nm are used, which lowers the efficiency in eliminating pathogens. A more consistent power output over the full range of wavelengths is needed (260-280 nm) and longer lifetimes would make this more suited for implementation. Further research and engineering developments are needed to optimize the technology for industrial implementation.

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Smart Spray Drying

MONASH University

Background

Many dairy products, including baby formula and milk, are sold in powder form, which allows for a longer shelf life than fresh dairy products. Spray drying is a technique often used to turn fresh milk into powdered milk. Spray drying works by rapidly heating a liquid or slurry with hot gas to turn it into powder. Spray drying using slurries at higher solid concentration improves the efficiency of the process as well as decreasing the energy cost, but a thicker slurry makes the flow of the feed more difficult and could potentially cause blockages in the pipeline. Researchers are investigating the use of hydrodynamic cavitation (HC) as a pre-treatment to spray drying to resolve this issue.

At a glance

Type: Hydrodynamic cavitation pre-treatment for spray drying

Current Application: Milk

Key Feature: Improved drying efficiency

Applicability: Any powdered food product

Year: 2018

Main Limitation: Pilot plant not set up yet

Smart Spray Drying

MONASH University

Technology

HC is a physical method that involves passing the liquid through a bottleneck to build up pressure, which is then released as kinetic energy in the liquid, creating both a mixing and a heating effect in the liquid. This technique can be used with any powdered food products that utilized spray drying.

Figure: A pilot scale spray dryer in the Monash University food grade lab. Credit: Monash

Smart Spray Drying

MONASH University

Benefits

- This technique can be used wherever spray drying is already used in the food industry (powdered dairy products, dry seasonings, and instant meals)
- It has been shown that the use of HC is effective at reducing the viscosity of the feed slurry such that feed flow is not impeded
- The use of HC maintains or even improves the functionality of the final powder product, such as its solubility in water

Drawbacks

- This method has not been tested in pilot plants, so cost information for the treatment is not yet available
- Temperature and pressure during the HC process needs to be controlled to prevent runaway reactions; equipment specially made to handle the high temperatures and pressures possible may be needed

Smart Spray Drying

MONASH University

Conclusion

Using hydrodynamic cavitation as a pre-treatment in spray drying can potentially improve the drying process and extend the shelf life of powdered dairy products. This is especially important for infant formulas, which are often exported overseas and may not reach the consumer for months after production. Monash University is working with a number of national and international industry partners on this project. Partners include CSIRO, Tamu Innovations, Bega Cheese, and Burra Foods, among others.

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Microchip-Pulsed Electric Field

Background

Pulsed electric field (PEF) is a popular nonthermal food preservation technology that works by delivering short (in the order of microseconds) high-voltage electric pulses to beverages that flow in between the two electrodes of the treatment chamber. These pulses destroy cell walls of microbes, causing cell death. The high voltages needed by this treatment are due to the strength of the electric field needed to trigger cell wall destruction. By using microchips, which allows the two electrodes to be very close together, even low voltages are able to produce high electric field strength, which makes it less expensive to run than traditional PEF instruments.

At a glance

Type: Nonthermal, electric

Key Feature: Nonthermal and nonchemical antimicrobial

Year: 2018

Current Application: Blueberry juice

Applicability: Fruit juice

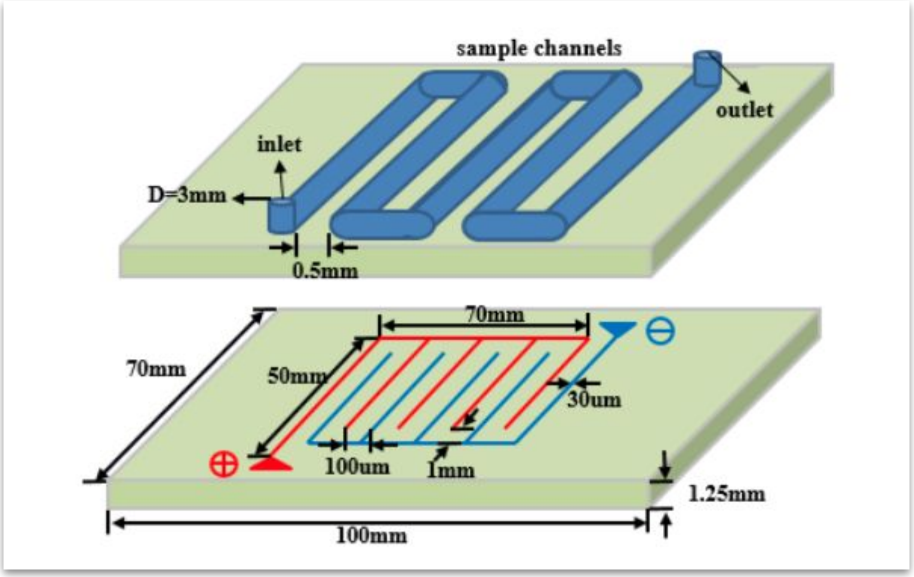
Main Limitation: Very slow flow rate

Microchip-Pulsed Electric Field

Technology

Both positive and negative electrodes are placed on the microchip, and the sample channel is placed above the electrodes. Blueberry juice is used as a sample and is passed through the channel while exposed to electric pulses from the electrodes. The odor and taste of treated blueberry juice (using microchip-PEF) were compared to that of fresh untreated blueberry juice using e-Nose and e-Tongue equipment and no significant difference was observed. It was found that the shelf life of the juice reached 30 days with this treatment, with no significant losses in vitamin C or acid content.

Figure: Schematic of a microchip with the detailed topology parameters. The multi-electrode array (red and blue lines) was etched on a glass basement membrane, and sample channels were etched on the PDMS and set on top of the electrode.



Microchip-Pulsed Electric Field

Benefits

- Visual, odor, and taste characteristics of final product did not significantly change
- No significant losses of nutritional content of final product because treatment is nonthermal
- Lower voltage is needed compared to traditional pulsed electric field technologies

Drawbacks

- Further research is needed to show that a viable high flow microfluidic system suitable for industrial applications is possible.
- Effect on other fruit juices, or other beverages in general, has not been investigated.
- The efficacy on high viscosity fluids remains a highly likely limitation.

Microchip-Pulsed Electric Field

Conclusion

The researchers believe that microchip-pulsed electric field could be a better alternative than high-temperature short time (HTST) treatments for the sterilization of fruit juices. Further research should focus on scaling up processes and optimizing the technique to maintain the characteristics of treated beverages.

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eBeam Technology

Background

Methyl bromide has been a choice for use as an antimicrobial agent for fruits and vegetables. It is highly effective but can be dangerous to the ozone layer and human health. To reduce the use of methyl bromide, the U.S. Department of Agriculture's Animal and Plant Inspection Service (APHIS) uses vapor heat, hot water dips, and cold treatments as alternatives. However, most of these treatments are ineffective and affect fruit quality. These techniques are especially problematic for mangoes. Mangoes, if too ripe, are unfit for hot water treatment, and the process of gamma irradiation is equally slow for them. APHIS has recently allowed the use of eBeams at 0.150-1 kGy to irradiate imported fruits and vegetables to ensure disinfestation.

At a glance

Type: Ionizing radiation technology

Key Feature: Chemical free, nonthermal, foodborne microbial DNA inactivation

Year: 2017

Current Application: Mangoes

Applicability: Milk, raw oysters, ground beef, spices, spinach, lettuce, and guavas

Main Limitation: Consumer resistance, slow commercial applications, labor intensive

eBeam Technology

Technology

eBeam technology is an example of ionizing radiation technology. An accelerator generates electrons with incredible velocity and high energy. These energetic electrons can penetrate food particles and cause numerous double-stranded breaks in the DNA, rendering microbial pathogens ineffective. The electrons can further split water molecules and generate short-lived free radicals, which in turn add to the inactivation of the microorganisms.

Food	Specific Application	Maximum Allowable Dose
Fresh, nonheated processed pork	Pathogen control	0.3–1.0 kGy
Fresh/frozen uncooked poultry products	Pathogen control	3 kGy
Refrigerated, uncooked meat products (sheep, cattle, swine, and goat)	Pathogen control	4.5 kGy
Frozen uncooked meat products (sheep, cattle, swine, and goat)	Pathogen control	7 kGy
Fresh/frozen molluscan shellfish	Pathogen control	5.5 kGy
Fresh shell eggs	Pathogen control	3.0 kGy
Seeds for sprouting	Pathogen control	8.0 kGy
Fresh iceberg lettuce and fresh spinach	Pathogen control	4.0 kGy
Dry or dehydrated spices and food seasonings	Microbial decontamination	30 kGy
Dry or dehydrated enzyme preparations	Microbial decontamination	10 kGy
Fresh produce	Growth and maturation inhibition	1 kGy
Fresh produce	Insect disinfestation	1 kGy
Wheat flour	Mold control	0.5 kGy
White potatoes	Inhibition of sprouting	0.15 kGy

Figure: The FDA has specified eBeam doses at which specific foods can be processed for controlling pathogens and extension of shelf life.

eBeam Technology

Technology

A representative list of the eBeam doses in kGy has been generated for different foodborne pathogens in different food matrices by the research group led by Dr. Pillai, director of the eBeam Center at Texas A&M University. In a study, eBeam-pasteurized milk met all the nutritional guidelines of the U.S. Department of Agriculture (USDA). Further, no off odors were generated.

Research has demonstrated that eBeam-treated mangoes could be stored for months under refrigeration without any damage in quality compared to mangoes treated with hot water. A major retailer has partnered with the eBeam center to meet federal sanitation requirements without damaging the fruit. More than one million 5-pound boxes of imported mangoes would get treated for sterilization and extension of lifespan. The goal of the collaboration is to test the use of this cost-effective, eco-friendly technology for commercial use. Moreover, the FDA has approved eBeam for the shelf life extension of foods at high risk for pathogens, such as meats, oysters, spinach, and lettuce.

eBeam Technology

Benefits

- eBeam technology eliminates the usage of methyl bromide for the sterilization of food products
- The commercial dose of eBeam applied to the food product is dependent on the target pathogens and is tunable, with no effect on the quality of the food product
- Mangoes treated with eBeam technology remain ripe for longer
- The technology is a cost-effective solution

Drawbacks

- Commercial applications of the technology have been slow
- Some consumers are resistant to the idea of using irradiated food products
- Currently, the process is labor-intensive, and therefore, the next step would be to test automation in the handling of the food products
- Possible health concerns could emerge due to the use of dosages at off-limits
- A thorough risk-based assessment of the dosage needed to sterilize the food products is required

eBeam Technology

Conclusion

Dr. Pillai is currently working to expand the technology by partnering with private companies and public agencies. Private companies are showing an increased interest in building similar eBeam centers in the United States and Mexico. The eBeam center is currently conducting a quantitative microbial risk assessment to measure the reduction in potential infection risks for the technology.

The scope of this technology is immense, as high volumes of food products can be treated with the fine-tuning of the dosage, with no chemical residues.

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Low-Temperature Drying

University of Nottingham
UK | CHINA | MALAYSIA

Background

Retention of the nutrients in our food from field to fork has remained a challenge for the food industry. Researchers from the University of Nottingham, Malaysia, have developed low-temperature drying to improve the shelf life and the quality of food. Compared to the traditional drying treatment, low-temperature drying is an efficient technique to retain flavor, color, bioactive ingredients, vitamin C, and other nutrients in processed foods. While the conventional drying methods improve shelf life by delaying the spoilage of food, this method results in a higher-quality product with higher nutrient content.

At a glance

Type: Low-temperature drying

Key Feature: Dehydration at low temperature, retention of color, taste, bioactive ingredients, and nutrients

Year: 2018

Current Application: Cocoa beans, fruits, herbs, and edible bird nests

Applicability: Food products in humid environments, minimize harvest loss

Main Limitation: Slow commercialization

Low-Temperature Drying

University of Nottingham UK | CHINA | MALAYSIA

Technology

Researchers from the University of Nottingham, Malaysia, discovered that drying lemon myrtle at a lower temperature of 20°C led to significantly improved retention of color and of the bioactive ingredient citral than using conventional drying methods at a temperature of 60°C. Since the discovery, low-temperature drying has been used to retain bioactive ingredients and nutrients in cocoa beans, fruits, herbs, and edible bird nests, a delicacy in East Asia.

The technique uses the combination of a heat pump system and heat transfer module to generate a low-temperature, low-moisture environment for dehydrating food products. The process is performed as a closed-system operation to minimize the chances of contamination. The lemon myrtle leaf powder is spread over a large surface to make the process more efficient.

After drying, air is recycled within the system and a condenser to extract the moisture from the air. An environment of 20°C and 20% humidity is optimum for removing the moisture from foods and herbs, which are sensitive to high temperature and contain bioactive ingredients.

Low-Temperature Drying

University of Nottingham
UK | CHINA | MALAYSIA

Benefits

- Low-temperature drying eliminates the risk of undesirable chemical reactions that generally take place in other processing conditions such as high temperature drying
- It improves the retention of bioactive compounds, nutritional content, and color
- Compared to thermal drying, drying at low temperature is energy efficient and cost effective

Drawbacks

- Commercialization has been slow for this technique due to the capital cost of using a closed system/controlled environment
- The process is much slower than high-temperature drying

Low-Temperature Drying

Conclusion

The research has generated widespread interest in industries, and the group is currently working to further improve the technology for collaboration and commercialization in the future. Low-temperature drying is a cost-effective and efficient solution for many companies looking to improve production processes, productive quality especially with products highly sensitive to high temperatures.

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Thermosonication of Apple Juice

Background

Ultrasound has the ability to inactivate microorganisms in two ways: mechanically, through the shear force generated that ruptures cell walls, and chemically, through the formation of free radicals that can also attack cell membranes and causes cell death. Combining ultrasound and thermal treatments (“thermosonication”) has been found to be an effective method for eliminating microorganisms. Researchers are looking into adding the antimicrobial peptide nisin to this method to see if it can prolong the shelf life of apple juice. Nisin is a peptide produced by the bacteria *Lactococcus lactis* that has been used as a preservative in the food industry for years.

At a glance

Type: Nisin-assisted thermosonication

Key Feature: Antimicrobial, preservative

Year: 2017

Current Application: Apple juice

Applicability: Fruit and vegetable juices

Main Limitation: Not enough testing done on taste

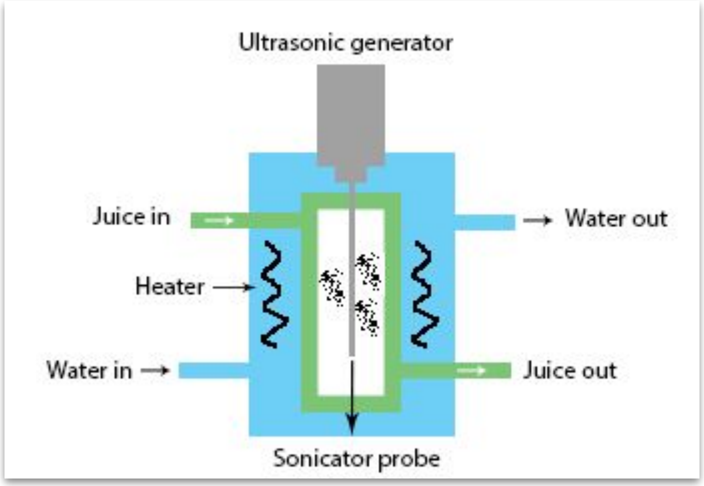
Thermosonication of Apple Juice

Technology

The treatment consists of adding a small quantity (50-200 ppm) of nisin in 100 mL of apple juice before putting the sample inside an ultrasonic processor with a water bath to control the temperature of the sample. The treatment was conducted at 52°C for 30 minutes. It was found that:

- ➔ The nisin and thermosonication combination decreased microbial activity significantly more than either individual method
- ➔ Juices treated with this combination had microbial levels low enough to still be safe for consumption after 15 days, while untreated juices would no longer be safe to drink

Figure: Schematic illustration of the thermosonication process.



Thermosonication of Apple Juice

Benefits

- The combination of methods (thermal, sonication, and nisin) was effective on a wider range of microbes than any one method alone
- Treatment conditions were mild and time required was relatively short (52°C, 30 min)
- Nutritional and visual values of the final product were not significantly altered
- This treatment has also been shown to work on products like carrot juice

Drawbacks

- Thermosonication has been shown to be more effective for acidic beverages (apple juice), so this may not be applicable to all types of beverages
- The effect of this treatment on the taste of the product has not been studied

Thermosonication of Apple Juice

Conclusion

Thermosonication has been tested with a number of different juices. However, this research shows added efficacy with the addition of antimicrobial peptides (nisin in this case) to the process, opening the door for further research and experimenting.

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Next Steps

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About the Authors

Paula Hock, PhD

PreScouter

Professional Summary:

Paula is one of PreScouter's Project Architects and is one of the Primaries in the Transportation Segment. She has worked on a wide variety of projects in her tenure, including topics like coatings and materials research, process optimization in many industries, comparative intelligence, and more. Paula earned her B.S. from DePaul University in Chemistry before continuing on to her Ph.D. in Physical Chemistry at the University of Pittsburgh. There, her research focused on characterization of organic semiconducting thin films for use in electronic devices. That is also where she started with the PreScouter Global Scholars program in August of 2014. After working as a scholar for a few months, she became a Team Leader before eventually taking a full-time role with PreScouter.

About the Authors

Navneeta Kaul, PhD

University of Denver, USA

Professional Summary: Navneeta Kaul recently completed her PhD in Biology at the University of Denver in Colorado. After earning an engineering degree in Biotechnology, her passion for cutting-edge biological research motivated her to pursue her Master's at the University of Arizona in Tucson. At the University of Denver, she studied the biological mechanism behind Fragile X syndrome, an autism spectrum disorder affecting nearly 1.3 million adults in the United States.

Research Background: Navneeta graduated with a Ph.D. in Biology from the University of Denver in August 2018. The focus of her research was to understand the mechanism of local protein synthesis at the synapse which is important for memory formation in vertebrates. She has experience in using biochemical and molecular biology techniques like cloning, PCR, real-time PCR, western blotting, immunoprecipitation, live cell, and fixed cell imaging.

Scientific Interests: Biotechnology, Life science consulting, Scientific communication, Microscopy, Engineering, Market research analysis, Business development.

About the Authors

Natasha Jane Chrisandina

Georgia Institute of Technology, USA

Professional Summary: Natasha recently completed her Master's of Science in Chemical Engineering at the Georgia Institute of Technology. While completing her degree, she worked on possible industrial extraction methods and applications for lignin. She has also written science articles for the PreScouter Journal, Massive Science Consortium, and Lateral Magazine.

Research Background: Natasha's research work focused on designing a process for more efficient solvent and water recovery during lignocellulosic biomass pretreatment for pulp mills and determining its economic and engineering feasibility. She also worked on investigating the mechanism of biomass depolymerization through mechanocatalysis.

Scientific Interests: Chemical process design, techno-economic analysis, lignocellulosic biomass, science communication

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Our model leverages a network of 2,000+ advanced degree researchers at tier 1 institutions across the globe to tap into information from small businesses, national labs, markets, universities, patents, startups, and entrepreneurs.

Clients rely on us for:

Innovation Discovery

PreScouter provides clients with a constant flow of high-value opportunities and ideas by keeping you up to date on new and emerging technologies and businesses.

Privileged Information

PreScouter interviews innovators to uncover emerging trends and non-public information.

Customized Insights

PreScouter finds and makes sense of technology and market information in order to help you make informed decisions.