Food Science and Technology Solutions to Improve Food and Nutrition Security:

Sustainable Production of Nutritious Foods Through Processing Technology

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About IFT

The Institute of Food Technologists (IFT) is a global organization of approximately 12,000 individual members from 95 countries who are committed to the science of food. The primary mission of IFT is to connect global food systems and technical communities to promote and advance the science of food. Science is essential to creating a global food supply that is sustainable, safe, nutritious, and accessible to all.

EXECUTIVE SUMMARY

For over 80 years IFT has engaged experts in food science and technology and related disciplines from academia, government, and industry to help solve many of the world's greatest food-related challenges. IFT's vision is for a world where science and innovation are connected and universally accepted as essential to improving food for everyone and the mission is to connect the global food system communities to promote and advance the science of food and its application.

IFT formed the Food & Nutrition Security Steering Committee (FNSSC) in 2021 to help identify key challenges in food and nutrition security and elevate food science and technology solutions. The FNSSC hosted a virtual roundtable discussion, "Enabling Food & Nutrition Security through Processing Technologies to Sustainably Preserve Nutritional Quality" on March 14 – 15, 2023. Building on the long-standing benefits of food processing, including improving availability, affordability, accessibility, acceptability and safety of the food supply, the goal of this roundtable was to expand upon existing and novel processing technologies that could help further preserve nutritional quality and contribute to food and nutrition security globally. Together roundtable participants explored the global opportunities and challenges to adoption of such technologies.

With a growing global population, climate-challenges, and unpredictable crises, such as pandemics, wars, droughts, floods, and other natural disasters, the time is now to future-proof the food system. Food processing is an essential bridge in the food system connecting farm to fork and beyond and ensuring food and nutrition security. Processing technologies offer a sustainable, scalable, and affordable way to simultaneously improve the availability and nutritional quality of foods to help ensure food and nutrition security for all. Numerous emerging technologies are focused on preserving food safety and quality while improving nutritional value and minimizing the impact to the environment.

Further development, scaling, and adoption of these emerging technologies can contribute to a more nutritious, sustainable, and safe food supply and improve global food and nutrition security. However, there are challenges to overcome. New technologies often take many years and significant investment, but this can be accelerated with public-private partnerships and multistakeholder investment. Cost and system optimization is also needed to ensure affordability. Acceleration of regulatory approvals as well as adequate training and support of the workforce in the implementation of these new technologies is also essential.

In developing countries, challenges exist even for traditional technologies, such as lack of reliable power sources, investment capital, trained personnel, distribution infrastructure, and adequate regulatory oversight to ensure safety. The implementation of sustainable processing in these regions must be simple and extremely cost efficient to be locally affordable and provide adequate support and training.

The importance of accurate, science-based communications in collaboration with multiple stakeholders across the food value chain is also critical to avoid consumer confusion and rejection of technology. The conflation of processing and food formulation in the development of food classification systems that classify “processed” foods as less healthy is an example of the consequences of a lack of multidisciplinary collaboration. Creating a perception of processed foods as bad for health hinders current innovations that are finding more sustainable ways to create more nutritious foods to ensure food and nutrition security for the growing global population.

Similar to the development of Good Manufacturing Practices (GMP) that ensure food safety, the concept and application of “Good Processing Practices” could be developed and implemented as standards which optimize nutritional quality and consumer acceptability of food using processes that are more environmentally sustainable. In addition to the embedding of sustainability and nutrition principles, these practices could involve a coordinated approach across the food value chain to achieve a future with greater food and nutrition security.

IFT Food & Nutrition Security Steering Committee (FNSSC)

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Virtual roundtable discussion, "Enabling Food & Nutrition Security through Processing Technologies to Sustainably Preserve Nutrient Availability"

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INTRODUCTION

The global population is estimated to reach 9-10 billion by 2050 from 8 billion today, and transdisciplinary approaches across all segments of the food value chain, from production, processing, packaging, storage, delivery, consumer use, and waste management, are necessary to ensure feeding a growing world with finite resources. Food processing is necessary for the conversion and preservation of raw materials to create safe, edible, nutritious, culturally acceptable food products that can be optimized for palatability and health and is an important and necessary link between food production and consumption (Figure 1). Food processing can be defined as the use of methods and techniques involving equipment, energy, and tools to transform agricultural products, such as grains, meats, vegetables, fruits, and milk into food ingredients or products (*https://www.ift.org/policy-and-advocacy/advocacy-toolkits/food-processing*). Attention to sustainable food processing to reduce food waste and increase nutrient bioavailability must be considered if UN Sustainable Development Goals, which include zero hunger, good health and well-being, and responsible consumption and production, among others, are to be reached by 2030.

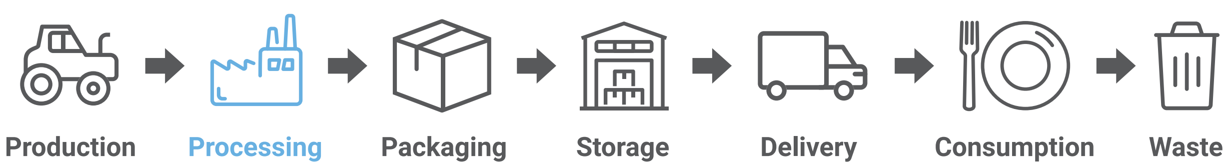


Figure 1. Food Processing is an Important Link in The Food Value Chain

The IFT FNSSC virtual roundtable discussion, “Enabling Food & Nutrition Security through Processing Technologies to Sustainably Preserve Nutritional Quality” held on March 14 – 15, 2023 aimed to identify food processing technologies that deliver safe, nutritious, sustainable foods that are affordable, accessible, and acceptable to consumers. The challenges to adoption of such technologies, globally, were also explored.

SDG2: End hunger, achieve food security and improve nutrition and promote sustainable agriculture.

SDG3: Ensure healthy lives and promote well-being for all at all ages

SDG12: Ensure sustainable consumption and production patterns

SDG icons sourced from *https://www.un.org/sustainabledevelopment/news/communications-material/*

THE IMPORTANCE OF FOOD PROCESSING IN THE SUSTAINABLE PRODUCTION OF NUTRITIOUS FOODS

Food processing has been around since the prehistoric age with simple technologies such as sun drying, preservation with salt, fermentation and roasting. These technologies were critical at the time to ensure food was edible, somewhat preserved, and safe. With the advent of electricity and the industrial revolution, technologies advanced to preserve foods for longer and produce them on a larger scale. Today technologies continue to develop to preserve the nutritional quality and safety of food while minimizing the impact on the environment (Figure 2)(1).

Important Distinctions between Food Processing and Formulation

Food processing and formulation are fundamental to making food, whether in a home kitchen or at a large scale. Food processing is the use of methods and techniques involving equipment, energy, and tools to transform agricultural products into food ingredients or products (*https://www.ift.org/policy-and-advocacy/advocacy-toolkits/food-processing*), and includes cooking and preservation techniques that impact taste, enhance shelf life, and contribute to food safety and quality (2). It can also impact nutrient bioavailability and bioaccessibility in foods. Food processing can be performed commercially, by the food industry, or at home, in the preparation of raw food materials for consumption. Food formulation is the iterative process by which ingredients are systematically chosen and combined to develop a finished food with desired characteristics. Similar to home food preparation, formulation is like the recipe of ingredients (and potential modifications to those

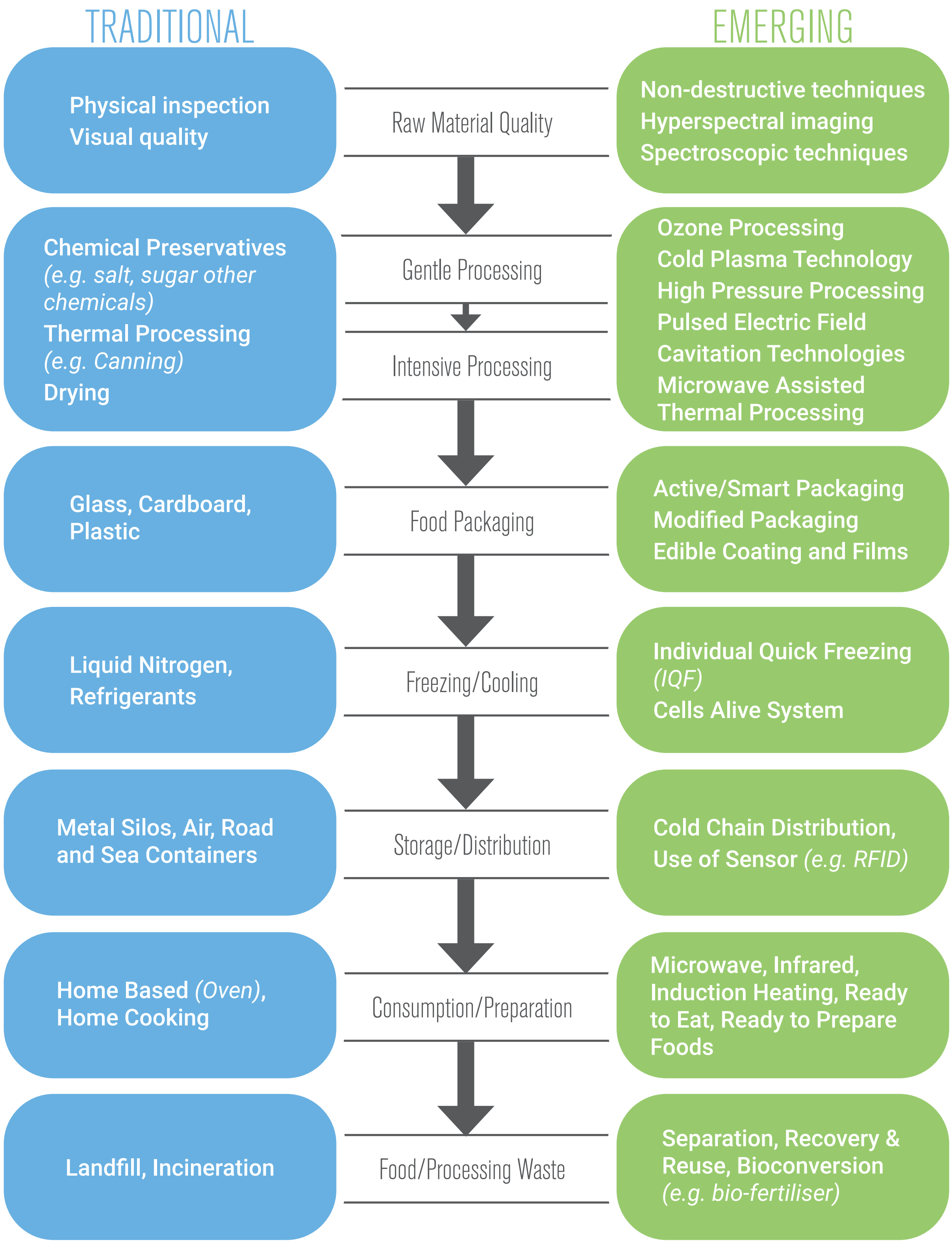
Food processing is the use of methods and techniques involving equipment, energy, and tools to transform agricultural products into food ingredients or products.

Food formulation is the iterative process by which ingredients are systematically chosen and combined to develop a finished food with desired characteristics.

ingredients) to make a desired food, while processing includes the techniques and steps taken to prepare the food with desired characteristics (e.g., cutting, baking, steaming, etc.). Food formulation and processing are both needed since it is critical to understand what will happen to specific ingredients during processing and ensure the final food has the desired characteristics and overall quality.

Some current initiatives focused on nutrition and public health conflate the lines between processing and formulation. This has led to consumer confusion and the misconception that processing alone makes foods less nutritious and sustainable for people and planet. For example, the NOVA classification system uses terminology such as “processed food” and “ultra-processed food” that are based primarily on the formulation of the foods and less about how the foods are processed or their nutritional value (Table 1) (3). The NOVA classification system also elevates home preparation as preferred and industrial as largely negative. Yet the main differences between home and factory are the scale and equipment used, while the processes are similar. The scale and equipment used in factories are designed to make the process more efficient and affordable and enable the production of food for a large number of people. However, in some cases, the same product (e.g., a loaf of bread, pasta sauce) made with similar ingredients and having a similar nutritional value would be classified in different categories according to NOVA due to the location where the product is made (home vs. factory).

Figure 2. Traditional and Emerging Technologies and Approaches used Along the Food Value Chain*



* Reprinted and adapted from Knorr D, Augustin MA, and Tiwari B (2020) Advancing the Role of Food Processing for Improved Integration in Sustainable Food Chains. Front. Nutr. 7:34. doi: 10.3389/fnut.2020.00034 (1)

Table 1. NOVA Food Classification and Considerations

<table>
<tr><th>NOVA Classification</th><th>Definition</th><th>Considerations</th></tr>
<tr><td>Group I: Unprocessed or minimally processed foods</td><td>“Unprocessed (or natural) foods are edible parts of plants (seeds, fruits, leaves, stems, roots) or of animals (muscle, offal, eggs, milk), and also fungi, algae, and water, after separation from nature.

Minimally processed foods are natural foods altered by processes that include removal of inedible or unwanted parts, and drying, crushing, grinding, fractioning, filtering, roasting, boiling, non-alcoholic fermentation, pasteurization, refrigeration, chilling, freezing, placing in containers and vacuum-packaging.”</td><td rowspan="4">Groups 1 – 4:
Utilize both traditional and emerging processing technologies

Help ensure safety for human consumption

Help ensure preservation to extend shelf-life and reduce food loss and waste

Help ensure accessibility, and in some cases affordability, of nutrients

Group 4:
Defined by formulation, and the role of processing to meet formulation demands, as opposed to the role of processing or number of processing steps, per se</td></tr>
<tr><td>Group 2: Processed culinary ingredients</td><td>“Processed culinary ingredients, such as oils, butter, sugar, and salt, are substances derived from Group 1 foods or from nature by processes that include pressing, refining, grinding, milling, and drying.”</td></tr>
<tr><td>Group 3: Processed foods</td><td>“Processed foods, such as bottled vegetables, canned fish, fruits in syrup, cheeses and freshly made breads, are made essentially by adding salt, oil, sugar, or other substances from Group 2 to Group 1 foods. Processes include various preservation or cooking methods, and, in the case of bread and cheese, non-alcoholic fermentation. Most processed foods have two or three ingredients and are recognizable as modified versions of Group 1 foods. They are edible by themselves or, more usually, in combination with other foods.”</td></tr>
<tr><td>Group 4: Ultra-processed foods</td><td>“Ultra-processed foods, such as soft drinks, sweet or savory packaged snacks, reconstituted meat products and pre-prepared frozen dishes, are not modified foods but formulations made mostly or entirely from substances derived from foods and additives, with little if any intact Group 1 food.”

“A multitude of sequences of processes is used to combine the usually many ingredients and to create the final product (hence ‘ultra-processed’). The processes include several with no domestic equivalents, such as hydrogenation and hydrolyzation, extrusion and molding, and pre-processing for frying.” Ingredients of these formulations may include extracts, such as casein and gluten, or processed ingredients, such as protein isolates, maltodextrins, and high-fructose corn syrup. They may also include additives, such as dyes, colors flavors, non-sugar sweeteners, and processing aids.</td></tr>
</table>

Reference: Monteiro CA, Cannon G, Moubarac JC, Levy RB, Louzada MLC, Jaime PC. The UN Decade of Nutrition, the NOVA food classification, and the trouble with ultra-processing. Public Health Nutr 2018;21(1):5-17. doi: 10.1017/S1368980017000234.

Food Processing Can Improve Nutrient Bioavailability

The food matrix affects how foods are digested, absorbed, and metabolized, indicating that the effect of foods on human health cannot be determined by simply considering the nutrients in foods. Food processing technologies, such as heating, dehydration, grinding, and mixing, enzymatic treatment, microwave, high pressure processing, and fermentation, designed to ensure the safety, preservation, and palatability of foods, can also modify the food matrix, and alter the bioavailability of nutrients.

As nutrition guidance shifts toward more plant-based eating patterns, challenges to micronutrient availability have been identified in the absence of diverse food systems. For instance, animal-sourced foods are important sources of high-quality protein and micronutrients. A shift toward plant-based diets is likely to lead to relatively lower intakes of high-quality protein, vitamins B2, B12, D, iodine, zinc, iron, calcium, and selenium (4). Further, the bioavailability of micronutrients from plant-based foods can be negatively impacted by antinutritional factors such as phytic acid, enzyme inhibitors, phenolic compounds, and saponins present within the plant food matrix (5). Many of these antinutritional factors can be minimized with appropriate food processing, thereby improving bioavailability.

Fermentation is an example of a processing technology that can modernize ancient knowledge to potentially improve bioavailability. There are several different mechanisms by which fermentation can alter the food matrix and enhance the macronutrient digestibility and micronutrient bioavailability of plant-based foods. Traditional fermentation has been demonstrated to increase protein digestibility by degrading complex proteins into simpler peptides and amino acids for digestion and absorption. It has also been shown to improve starch digestibility by activating starch-hydrolyzing enzymes, such as alpha-amylase and maltase. Further, micronutrient bioavailability may be improved through fermentation by improving anti-oxidative attributes and enhancing phytase production that releases free mineral ions (6). Novel protein sources developed through emerging technologies, such as precision fermentation, can also meet emerging demands for more plant-based eating patterns with less demand for animals, energy, and carbon.

Food Preservation Contributes to Sustainable Food and Nutrition Security and Diverse Diets

Food preservation is a critical to achieving sustainable food and nutrition security and diversifying diets. The primary goal of food preservation is to maintain quantity and quality of food from production to consumption, without compromising safety, taste, or nutrition. Common preservation techniques include cooling, dehydration, and heating to prevent the spoilage of food and extend shelf-life (Table 2).

Emerging food preservation technologies are being developed that can use less energy, minimize nutrient loss, and improve taste and texture quality, without compromising on food safety (Table 2). A challenge to adopting these novel technologies is the substantial research investment that must be committed to concept development, pilot-scale testing, regulatory acceptance, and scale-up and production, which can take several decades and millions of dollars. Additionally, uptake of new and disruptive technology is often slow due to lack of knowledge, training, and resources, particularly in small businesses and start-ups which are usually the early adopters of new technologies. There is also a lack of accurate and transparent data to determine engineering feasibility, economic viability, and sustainability of new technologies.

Table 2. Preservation Techniques and Associated Food Safety Concerns

Common Preservation Technologies	Emerging Preservation Technologies	Common Foods	Leading Food Safety Concerns
Cooling Refrigeration Freezing	Individual quick freezing Isochoric freezing Pressure-assisted freezing	Fresh Fruits Fresh Vegetables Meat Fish Dairy Eggs	*Listeria monocytogenese* *Salmonella* *Escherichia coli* O157:H7 Norovirus
Dehydration Hot air drying Freeze drying Spray drying Drum drying	Microwave drying Radio frequency drying Superheated steam drying Refractance window drying	Low-Moisture Fruits Low-Moisture Vegetables Spices Infant Formula Ingredients	*Listeria monocytogenese* *Salmonella* *Escherichia coli* O157:H7 *Bacillus cereus*
Heating Pasteurization Sterilization	Aseptic processing Ohmic processing High pressure processing Pressure-assisted thermal processing Pulsed Electric Field Microwave Shaka-retorting Pulsed light Radio Frequency Plasma Electrolyte water Ultraviolet-C Ultrasound Ultrashear technology	Milk Ready-to-Eat Meals Fruits Vegetables Meat Seafood	*Listeria monocytogenese* *Salmonella* *Escherichia coli* O157:H7 Clostridium *botulinum* spores (sterilization)

References: (7-10) Check out more processes at IFT's Food Processing Toolkit at https://www.ift.org/policy-and-advocacy/advocacy-toolkits/food-processing

Overcoming Challenges to Developing and Implementing More Sustainable Processing Technologies to Ensure Nutrition Security

To overcome the time and investment challenges noted above, future research programs could focus on funding diverse and sustainable food production and processing technologies with potential for high impacts that have at least been validated at production scale. Funding structures, such as those for Small Business Innovation Research (SBIR) could provide greater levels of funding for high impact projects along with matching to better enable small companies to acquire IP and scale-up technologies. University researchers can use the opportunity for educating next generation of industrial workforce with relevant skills.

Uptake of new technologies may be improved if small to medium food companies can access publicly funded networks of pilot scale facilities in land-grant universities or research institutions to demonstrate and test new concepts. Further, providing workforce training to early adopters may improve acceptance of new technologies. Standardized assessment matrices and development roadmaps could help provide the data needed for companies and regulators to make informed decisions on new technologies.

Up-to-date and aligned regulations could also open the door for more sustainable practices. The transdisciplinary research necessary to test effects of novel processing technologies on human health and safety is often cost prohibitive and requires public-private support from multiple sectors. In some cases, private sector funding is driving the development of innovative technology that isn't compatible with current regulations, highlighting the need for public-private collaboration. Additionally, many novel processing technologies have been successfully launched by small and medium size companies, but those technologies have not necessarily been optimized to meet the needs of different food companies, which limits industrial implementation. Often these small and medium size companies do not have financial resources to sponsor university researchers on R&D activities for system improvement and technology transfer. On the other hand, many larger corporations may prefer to directly acquire successful small or medium size companies with novel processing technologies.

Misinformation about food processing and novel processing technologies can also hinder innovation, and ensuring accurate, science-based messages are reaching consumers and stakeholders is necessary to ensure regulatory and consumer acceptance of novel technologies. Multidisciplinary communication efforts must span across the food system if advances are to be made to achieve food & nutrition security.

The current regulatory climate is ripe for novel and sustainable processing technologies that can enhance food and nutrition security. Governments are proactively seeking transdisciplinary research support to build the scientific evidence base to implement novel processing technologies. For example, the definition of pasteurization was recently expanded to include thermal and nonthermal processes (11). Further, funding bodies are encouraging those looking to commercialize technology to partner with regulators early in the process to anticipate hurdles before research begins.

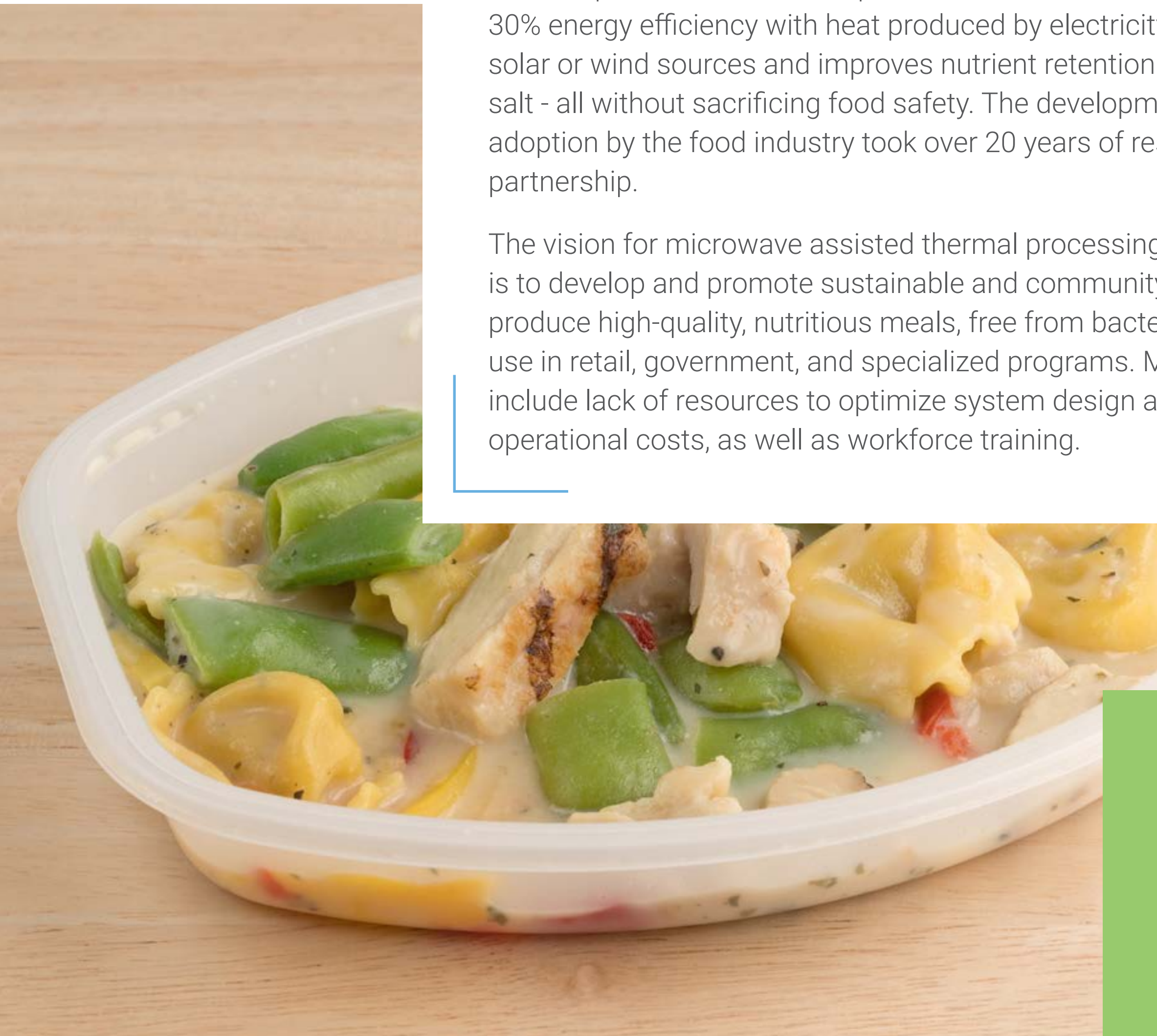
Case Study

Microwave Assisted Thermal Sterilization and Pasteurization Technologies To Preserve Nutrient Quality

A research partnership between Washington State University (WSU) and the US Department of Defense (DoD) with investment from industry and non-government organizations to develop and implement microwave assisted thermal sterilization (MATS), and later, with support from the US Department of Agriculture National Institute for Food & Agriculture (NIFA) program, pasteurization technologies, is an example of a public-private partnership that was able to create a more energy efficient preservation technology that could safely preserve nutrient quality in ready-to-eat (RTE) meals.

Traditional canning has approximately 10 - 15% energy efficiency with heat produced from boilers that utilize natural gas or coal as energy sources. While effective, the heat negatively impacts the appearance, nutritional quality, and often requires more salt to improve taste. In contrast, MATS has an estimated 30% energy efficiency with heat produced by electricity that can be derived from solar or wind sources and improves nutrient retention and lowers the need for salt - all without sacrificing food safety. The development of this technology and adoption by the food industry took over 20 years of research investment and partnership.

The vision for microwave assisted thermal processing technologies in the future is to develop and promote sustainable and community-based platforms to produce high-quality, nutritious meals, free from bacterial and viral pathogens for use in retail, government, and specialized programs. Major hurdles to this vision include lack of resources to optimize system design and reduce equipment and operational costs, as well as workforce training.



Case Study

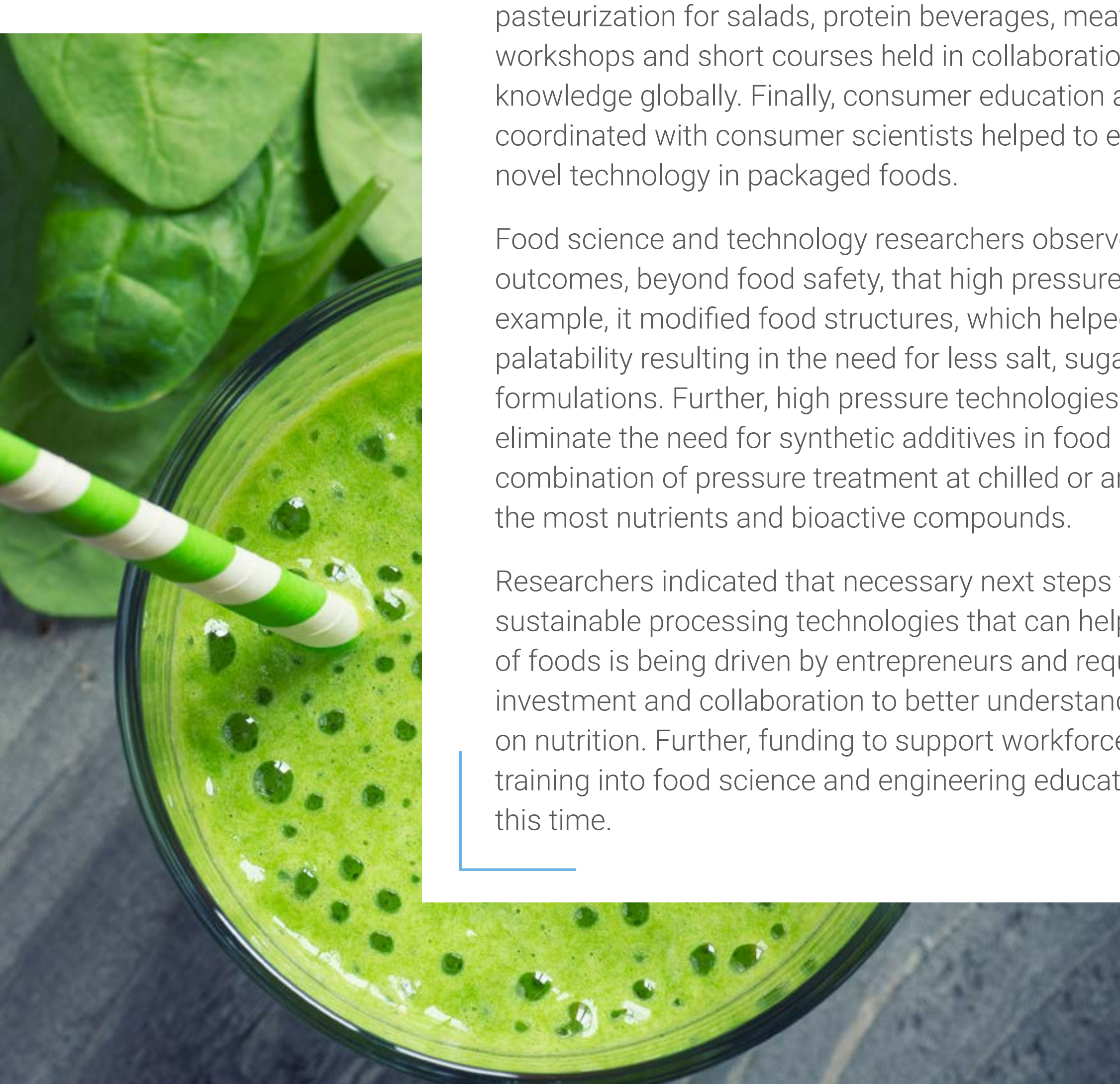
High Pressure Processing To Preserve Nutrient Quality

Another example of public-private research partnership that explored food processing innovation to improve the nutrient quality of food was high pressure food pasteurization and sterilization methods tested by The Ohio State University with funding from the US DoD, USDA NIFA, and the food industry. Methods tested included high pressure processing, pressure-assisted thermal sterilization, and pressure-ohmic thermal sterilization (12). Such research efforts enabled FDA to issue a letter of no objection for two pressure-assisted thermally sterilized products. Recently, as a part of USDA NIFA project, OSU researchers developed ultra-shear technology for clean label dairy and plant protein beverages and sauces (13).

The optimization of sustainable processing technology didn't stop in the lab. Researchers then held pilot plant demonstrations and bootcamps for processors as well as new regulatory inspector trainings. OSU Advanced Food Processing Technology pilot plant facility actively collaborated with interested food processors and equipment providers in demonstrating the benefits and limitations of various novel food processing technologies. OSU collaboration with various entrepreneurs enabled industrial implementation of high-pressure pasteurization for salads, protein beverages, meats, and oysters. Other workshops and short courses held in collaboration with IFT helped disseminate knowledge globally. Finally, consumer education and outreach that was coordinated with consumer scientists helped to ensure the acceptance of the novel technology in packaged foods.

Food science and technology researchers observed additional beneficial outcomes, beyond food safety, that high pressure technology had on foods. For example, it modified food structures, which helped maintain nutrient density and palatability resulting in the need for less salt, sugar, and fat in the final product formulations. Further, high pressure technologies also helped to reduce or eliminate the need for synthetic additives in food and beverage formulations. The combination of pressure treatment at chilled or ambient temperatures preserved the most nutrients and bioactive compounds.

Researchers indicated that necessary next steps to the scale-up of novel and sustainable processing technologies that can help improve nutrient bioavailability of foods is being driven by entrepreneurs and requires substantial public investment and collaboration to better understand the effects of processing on nutrition. Further, funding to support workforce development to incorporate training into food science and engineering education and practice is warranted at this time.



Case Study

Fermentation To Enhance the Nutritional Profile of Foods

Fermentation has been used for centuries to help preserve foods but can also enhance the nutritional content of the food. This traditional technology is now being leveraged in new and innovative ways to enhance the nutrient value of plant-based alternatives to animal foods. As an example, the market for plant-based beverages continues to grow, but often these products do not provide the same nutrients as their dairy counterparts. Fermentation of some of these plant materials with certain microbial strains has been shown to increase bioavailable protein, B vitamins, and reduce anti-nutrients, such as phytates and tannins (14). Fermentation can also improve the sensory profile of some plant-based beverages by creating desirable volatile flavors or improving appearance and viscosity.

Precision fermentation harnesses the power of microorganisms to produce desired food ingredients. For example, microorganisms can be precisely controlled and programmed to produce animal or plant proteins without the need for conventional farming practices or animals. This technology has the potential to achieve high yields of food ingredients with minimal impact to the environment and could potentially be used in areas where the climate or soil are not amenable to farming. The key challenges for precision fermentation are scaling the process while maintaining the precision needed for the biochemical processes.

Case Study

Filtration and Separation Processing To Enhance Nutritional Quality

Novel processes such as microfiltration, ultrafiltration, and nanofiltration can improve the safety and nutrient content of foods and beverages. For example, ultrafiltration has been used to increase the protein content of dairy products while simultaneously reducing the sugars, including lactose, in the milk. This technology has also been used to concentrate micronutrients in fruit juices and purees (15). Filtration technologies can also remove anti-nutrients, such as lectins or phytates in plant-based foods and enhance food safety by removing detrimental heavy metals in liquid foods (16, 17).

Implementing Sustainable Processing to Enhance Food and Nutrition Security: An Eye on Developing Nations

Just as in developed economies, implementation of sustainable processing to enhance food and nutrition security in developing nations requires transdisciplinary approaches across nutrition; food science, technology, and engineering; food safety; and regulatory. Public-private partnerships are important for implementation and acceptance and require the involvement of local communities in design and execution.

The benefits of sustainable processing to developing economies are similar to those of developed nations; however, the challenges differ. Benefits include improved food and nutrition security, such as through extended shelf-life that helps preserve food for year-round supply; improved food safety; reduced food waste; convenience; and added value that ultimately helps develop economies. Challenges to implementing sustainable processing in developing countries include a lack of reliable power sources, investment capital, trained personnel, distribution infrastructure, and adequate regulatory oversight to ensure safety. Adequate nutrition and safe food are important around the world, but these are persistent concerns in low-income countries. Sustainable processing must be extremely cost efficient to be locally affordable and implementation must be simple and provide adequate support and training.

Several case studies pertaining to nutrition enhancement and processing innovations in developing countries are available from the IFT International Division, Food Science for Relief and Development program (*https://info.ift.org/en/fsrd-21*). These include technologies such as rice extrusion to address hidden hunger, small scale soy processing equipment for microenterprises, and low-cost solar food dehydrators to minimize post-harvest losses and improve food security. Common threads that run throughout each of the case studies involve holistic and inclusive methodologies that emphasize the long-term development of food industries. They are built by consulting with local community partners to employ culturally appropriate and innovative solutions that are economically and technically feasible by region and are useful in both long-term and emergency relief situations.

FOOD PROCESSING: A BRIDGE TO FOOD & NUTRITION SECURITY

By 2050, 9.7 billion people are expected to populate the Earth. With an increased demand for nutritious foods coupled with the need for diversity, to conserve our natural resources, and ensure food safety, processing to enhance and preserve nutrition within food is an essential practice to ensure affordability, availability, accessibility, and acceptability of the global food supply. Processing offers a bridge to food and nutrition security for everyone. From reducing waste to enhancing the nutritional profile, processing can help maximize the benefit of foods while minimizing the impact on our natural resources.

A proposal for Good Processing Practices that embed sustainability and nutrition principles

As the demand to transition to more sustainable food materials increases, research initiatives that address novel processes and raw materials using less energy and water must include input from scientists and engineers across the value chain, from production to consumption. Much like Good Manufacturing Practices (GMP) that ensure food safety, the concept and application of "Good Processing Practices" could be developed and implemented as a regular standard within the food industry to optimize the nutritional quality and consumer acceptability of a food while conserving water and energy use. Additional strategies that will accelerate the development of sustainable, efficient, and acceptable food processing systems that utilize alternative energy and create scalable, safe products that optimize nutritional quality are warranted.

Good Processing Practices coordinate approaches across the food value chain

As the food and nutrition domains are evolving at an accelerated pace, the prevailing norms and siloed approaches are no longer sufficient. The competitive and complex landscape necessitates a new mindset and some paradigm shifts. There is a need to enhance collaboration among all members of the food value chain, which could be portrayed as a 4-helix ecosystem (academia-industry-Federal/State-private business) as proposed by Saguy et al. (18).

Coordinated approaches are also necessary to ensure communications that distinguish between food processing and formulation and recognize the benefits of food processing, such as in ensuring food safety, extending shelf life, reducing food loss and waste, and ensuring the accessibility and affordability of nutrition. These communications are critical to reduce consumer confusion and misclassifications of processing as detrimental to human health. This is also critical to ensure the continued development of sustainable processing technologies for food and nutrition security.

Conclusion

To feed a growing global population while conserving our limited natural resources, advances in sustainable processing technologies that preserve the inherent nutrition in food will be necessary. Food processing is under intense scrutiny in the public health arena and due to confusion with formulation, processing is often viewed as negative for health. However, processing of food is essential and can enhance nutrient bioavailability, improve food safety, and make foods more affordable and available. Emerging technologies that use less energy, minimize nutrient loss, and improve consumer acceptability are being developed, but greater investment is needed, particularly for high impact technologies, to bring these technologies to scale. Sustainable processing is also important in the developing world, but must be affordable and simple to implement. Coordinated approaches across the food value chain are needed to ensure the continued development, implementation, and acceptance of sustainable processing technologies that will feed the world
and protect the planet into the future.

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