

# Food Science and Technology Solutions to Improve Food and Nutrition Security: Reducing Food Loss & Valorizing Food Processing Side Streams

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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 and its application. Science is essential to creating a global food supply that is sustainable, safe, nutritious, and accessible to all.

“Mitigating food loss and waste isn’t just good for business and the planet, it is a moral imperative.”

### EXECUTIVE SUMMARY

For over 80 years the 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.

In 2021, IFT formed their Food & Nutrition Security Steering Committee (FNSSC) to help identify key challenges in food and nutrition security and elevate food science and technology solutions. In 2022, the FNSSC hosted a virtual roundtable discussion on their first challenge, “Food Science & Technology Solutions for Reducing Food Waste and Valorizing Waste Streams” on November 1 – 2, 2022. The goal was to identify current and potential future solutions from food science and technology that can contribute to the reduction of food loss and valorization of food processing side streams to improve food and nutrition security.

Food loss and waste is an environmental, societal, and economic problem. Approximately one third of food produced globally is never consumed, contributing to over a billion tons of food wasted each year costing the global economy almost a trillion dollars annually. Meanwhile, one in nine people worldwide is living in hunger. Food security is a global priority that is dependent on a sustainable food system that can address growing demand amidst resource depletion.

A sustainable food system produces foods that are desirable, inexpensive, nutrient dense, both environmentally and culturally responsive, and safe. Valorizing food processing side streams to mitigate food loss can improve economic, social, and environmental aspects of the current food system and encourage equal distribution of food from different geographical regions to help ensure food security, globally.

The roundtable discussion outlined the challenges, solutions, and opportunities in reducing food loss in the middle segment of the value chain and serves as a call to action to unite the food science and technology community in measuring food loss, investing in valorization of food processing side streams, and bringing the science of food into efforts aimed at mitigating food loss and waste.

In summary the discussion outlined the following challenges to overcome:

- Lack of measurement and target setting
- Food safety concerns
- Consumer acceptance and awareness
- Technological feasibility and scalability
- Communication and collaboration across the value chain
- Limited policy and investment

To address these challenges the food science and technology community will need to:

- Systematically evaluate food processing side streams for potential use as value-added ingredients for foods
- Advance technologies that ensure the safety, sustainability, and affordability of value-added ingredients from food processing side streams
- Better communicate with consumers the impact of food loss and waste and the benefits of foods made from upcycled ingredients
- Advocate for greater investment in scalable and affordable food science and technology innovations in developed and developing countries to reduce food loss
- Enhance food preservation with scalable, affordable technology
- Build collaborations across the food supply chain to ensure the sustainability and feasibility of technologies to reduce or valorize food loss.

While the roundtable highlighted several food science and technology solutions, the consensus was that policies and coordinated efforts across the food value chain are essential to bring to scale any solutions in reducing food loss and waste and valorizing food processing side streams. For these, the attendees recommend better quantifying the value of food, building, and strengthening cross-functional coalitions across the food supply chain, mapping and tracking food loss and waste, investing in processing and scaling innovation, and expanding policy around carbon offset to include valorization of food processing side streams.

This white paper is a step in a coordinated approach by the food science and technology professional community to align efforts at mitigating food loss from the middle segment. Strengthening these coordinated efforts among public and private sectors; allocating resources dedicated to food science and technology solutions; and legislative action are necessary to meeting global targets to reducing food loss while feeding the world.

## **IFT Food & Nutrition Security Steering Committee (FNSSC)**

Hongda Chen, PhD, USDA National Institute of Food and Agriculture  
Allen Foegeding, PhD, North Carolina State University (Professor emeritus)  
Alyson Greenhalgh-Ball, Conscious Impact  
Lamin Kassama, PhD, Alabama A&M University  
Ana Maria Quirós, University of Costa Rica  
Geoffry Smith, Essential Nutrients Foundation and International Life Sciences Institute, South East Asia Region  
Gulden Yilmaz, PhD, Wageningen University

## **Virtual roundtable discussion, “Food Science & Technology Solutions for Reducing Food Waste and Valorizing Waste Streams”**

### **Invited Speakers:**

Liz Goodwin, PhD, OBE, World Resource Institute  
William Chen, DSc, Nanyang Technological University  
Ziyet Boz, PhD, University of Florida  
Kiruba Krishnaswamy, PhD, University of Missouri  
Maddison Gurrola, Mattson  
Juan Andrade, PhD, University of Florida

### **Panelists:**

Laura Brenes-Peralta, PhD, Costa Rican Institute of Technology  
Daniel Kurzrock, Upcycled Foods, Inc.  
Joe Light, Food Loving Ventures, LLC  
Vijay Nandula, PhD, National Institute for Food and Agriculture  
Ana María Quirós, University of Costa Rica

### **Moderator:**

Kelly Hensel, IFT

### **IFT Listeners:**

Anna Rosales, RD  
John Ruff, CFS  
Lisa Sanders, PhD, RD

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# INTRODUCTION

It's been estimated that 14% of food valued at 400 billion USD is lost from harvest up to, but not including retail **\*Food Loss**, and another 17% is wasted at retail and by consumers **\*Food Waste**. By these estimates, food loss and waste cost the global economy 936 billion USD annually (3). Further, it's been estimated that food loss and waste are responsible for 8% of greenhouse gas emissions (GHG) (4) and a loss of one-quarter of freshwater that is used in global food production, but never consumed (5). Food loss and waste occur across the value chain, from production, through processing and packaging, to retail and consumer use (6). Meanwhile, 8.9% of the world's population is undernourished, with caloric intake below minimum energy requirements, and more than a quarter of the population, 2.3 billion people, are moderately or severely food insecure (7).

In 2015, the 193 Member States of the United Nations adopted seventeen Sustainable Development Goals (SDGs); global objectives expected to guide the actions of the international community through 2030 (8). It was noted that food and agriculture were key to achieving the entire set of SDGs with a focus on rural development and investment in agriculture as powerful tools to help end poverty and hunger, bring about sustainable development, and combat climate change (8). The twelfth SDG, "Ensure sustainable consumption and production patterns", set the following target and indicators specific to food loss and waste (8):

"It's been estimated that 14% of food valued at 400 billion USD is lost from harvest."

## Target 12.3

By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.

### Indicator 12.3.1 – Global Food Loss and Waste

SDG target 12.3 has two components, Losses and Waste that should be measured by two separate indicators.

#### Sub-Indicator 12.3.1a – Food Loss Index

The Food Loss Index (FLI) focuses on food losses that occur from production up to, and not including the retail level. It measures the changes in percentage losses for a basket of two main commodities by country in comparison with a base period. The FLI will contribute to measure progress towards SDG Target 12.3.

#### Sub-Indicator 12.3.1b – Food Waste Index

A proposal for measuring Food Waste, which comprises the retail and consumption levels is under development. UN Environment Programme is taking the lead on this sub-indicator.

**\*Food Loss:** Food lost from harvest up to, but not including retail

**\*Food Waste:** Food wasted at retail and by consumers

The urgency of mitigating food loss and waste is unparalleled. Food waste is not simply a consumer issue, nor is it simply a problem only in developed or developing countries. Food loss and waste is a problem across the value chain, in every corner of the planet, from low-income to high-income settings (2). Now is the time for more concerted efforts by policymakers and stakeholders in research and industry to act on mitigating food loss and waste, globally.

One of the areas where food science and technology can play a key role is in mitigating food losses within the middle segment of the food value chain (Figure 1). This white paper identifies the food science and technology challenges, opportunities, and solutions that can contribute to the reduction of food loss and valorization of food processing side streams to improve food and nutrition security. The solutions highlight the essential role of food science within sustainable food systems and food and nutrition security, while considering the relationships between sustainability; food safety; consumer acceptability; and food availability, affordability, and accessibility for all.

**Figure 1.** The **\*middle segment** of the food value chain



“One of the areas where food science and technology can play a key role is in mitigating food losses within the middle segment of the food value chain.”

**\*Middle Segment:** The segment of the food-value chain between primary production and retail and consumption that includes conversion and value-added processing and distribution and transport

# CHALLENGES IN MITIGATING FOOD LOSS IN THE MIDDLE SEGMENT

Mitigating food loss in the middle segment is challenging for several reasons including, but not limited to:

- Lack of measurement and target setting
- Food safety
- Consumer acceptance and awareness
- Technological feasibility and scalability
- Communication and collaboration across the value chain
- Limited policy and investment

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## Lack Of Measurement And Target Setting

“What gets measured,  
gets managed.”

World Resources Institute (WRI)

To date, many countries have not adopted good methodologies for measuring food loss and waste, and without a uniform measurement across the food system, it is difficult to accurately assess the issues. Whereas efforts are underway to develop uniform methodologies with the Food and Agriculture Organization (FAO) of the United Nations, progress is slow. Even without uniform measurement standards across the food system, however, it is imperative for industry to measure food loss and waste to effectively target critical areas for improvement and be able to measure progress against targets.



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## Food safety

The valorization of food processing side streams from the middle segment into foods and ingredients intended for human consumption is one strategy by which food loss can be mitigated. Food processing side streams; however, can contain physiochemical contaminants or pathogenic bacteria detrimental to human health, such as *aerobic mesophilic bacteria*, *coliforms*, *molds* and *yeasts*, *Salmonella*, *Eschericia coli*, and *Staphylococcus aureus* (9). Each novel side stream and source presents different food safety risks, which must be individually assessed and addressed. Physical properties must also be assessed because of impacts on quality, safety, and acceptability. Further, there are varying stabilities associated with value-added components during processing. Currently, there are limited data on effective measures to remove undesirable toxic contaminants and reduce pathogens to enable valorization of food streams.

Ownership of safety is also a consideration when valorizing food processing side streams. Co-products utilized as raw materials for foods and ingredients are subject to quality and safety regulations. Labeling considerations such as whether an ingredient has GRAS status in the US, or pre-approval as a novel food in the EU, impacts the utility of the innovation. Processors that may be interested in using food processing side streams may not be willing or able to absorb the cost of ensuring safety by removing physical, chemical, or biological contaminants from materials that would traditionally be considered waste products. Enacting quality and safety protocols throughout the supply chain could help ensure the safety and utility of side streams for valorization but may require legislation and financial support.

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## Consumer Acceptance and Awareness

Consumers consistently report taste as the most important food value to them (10). Data collected from two representative samples of the U.S. indicated that taste, safety, price, nutrition, and convenience were the top five food values of importance to Americans, which was consistent with previous investigations (10). As with any food venture, consumer acceptance and affordability is a consideration when developing food science and technology solutions to valorize food processing side streams in the middle segment.

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## Technological Feasibility and Scalability

Several innovative food science and technology solutions aimed at creating opportunities across the value chain for efficiency gains to lower food loss and waste exist but need to scale fast and be utilized throughout the global food system to meet food loss and waste targets by 2030 (11). Scaling-up is an arduous, complex process of managing risk and working cross-functionally to problem solve. Innovation that comes with lagging commercialization can slow overall impact. This quick and massive scale-up of innovative technologies will require substantial investment from public-private partnerships as well as commitment to adopt and promote these solutions from industry and government. Thus, substantial financial drivers will have to be recognized to secure investment in full scale technologies.

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## Communication and collaboration across the value chain

Mitigation of food loss and waste requires communication and collaboration across the value chain to ensure actions taken in one segment don't create challenges for another, such as driving up cost, introducing other environmental insults, or food safety risks. This is challenging given the complexity of global food systems that have multiple stakeholders invested. No one solution for mitigating food loss and waste has been identified, but communication, collaboration, and transparency are considerations when tailoring solutions that address critical control points along the value chain.

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## Limited policy and investment

“Food waste is a privilege. It is a byproduct of our desire for abundance and vanity towards visual perfection.”

(12)

Lack of policies related to minimizing food loss or regulations that enable approval of upcycled ingredients for novel value-added products has been identified as a barrier to broader scaling and implementation of these technologies (9). Currently, the European Union (EU) is a leader in legislative effort to ensure the safety of valorized food processing side streams, and does require a safety assessment of any novel food or food ingredient intended for human consumption (13). In the U.S., the Food and Drug Administration ensures food safety through the Federal Food, Drug and Cosmetic Act, and Food Safety Modernization Act, which regulates food additives, new dietary ingredients, pesticide chemical residues and foodborne illness prevention (14), but these laws do not adequately address safety assessment of valorized food side streams intended for human consumption.

# SOLUTIONS AND OPPORTUNITIES IN MITIGATING FOOD LOSS IN THE MIDDLE SEGMENT

“The business case for fighting food waste: for every \$1 companies invested in reducing food loss and waste, they saved \$14 in operating costs.”

The Consumer Goods Forum Food Waste Coalition of Action (15)

Despite the challenges associated with mitigating food loss and valorizing food processing side streams in the middle segment, food science and technology solutions and opportunities exist:

- Evaluate food processing side streams for potential use as value-added ingredients for foods
- Technologies that ensure the safety, sustainability, and affordability of value-added ingredients from food processing side streams
- Communications with consumers on the impact of food loss and waste and the benefits of foods made from upcycled ingredients
- Investment in scalable and affordable food science and technology innovations in developed and developing countries to reduce food loss
- Enhanced food preservation with scalable, affordable technology
- Collaborations across the food supply chain to ensure the sustainability and feasibility of technologies to reduce or valorize food loss.

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## Evaluate food processing side streams for potential use as value-added ingredients for foods

**The Circular Economy Model.** The circular economy model is one in which businesses create supply chains that recover or recycle the resources used to create their products (16). The circular economy model is appealing because of its potential to reduce environmental impacts, mitigate food loss, and create value (Applied Research Study 1). A report published by The Consumer Goods Forum found that for every dollar companies invested to reduce food loss and waste, they saved fourteen dollars in operating costs (15). Whereas a circular economy for food has the potential to interconnect components of the food system to create zero waste processing, the scalability of the circular economy presents challenges. The circular economy can be sustainable only if value can be economically recovered from the product - whether realized through reuse, extended shelf-life, upcycle, or value-add (17). It is dependent on external factors, such as policy, secondary markets, and consumer acceptance, and thus must be developed holistically with stakeholders across the value-chain.

## Case Study

### Applied Research Study 1:

#### **Circular Economy for Food Industry Waste**

**Nani M, Krishnaswamy K, ACS Food Science & Technology, 2023 (18)**

The dairy industry faces a significant challenge when it comes to acid whey. The by-product, largely produced as a side stream of Greek yogurt production, has a high biological oxygen requirement that can cause harm to the ecosystem making acid whey expensive to dispose of.

A feasibility study assessed the use of different concentrations of millet flour as an encapsulating wall material on the physio-functional properties of acid whey millet powders. Millet is a nutritionally dense and resilient grain that is frequently underutilized for human consumption in developed and developing countries due to a lack of awareness or its use for animal feed. Millet flours were demonstrated to have a neutralizing effect on acid whey that aided in the spray drying process. The process resulted in improved yield, color, and reconstitution properties of acid whey millet powders that also exhibited antioxidant activity because of the high concentration of phenolic compounds from the millet.

One of the key learnings from this study is the importance of understanding and solving for multiple issues when evaluating the feasibility of converting a food processing side stream into functional ingredients. This case study considered and solved for the material properties of the side stream, expanded the use of a nutritionally dense but underutilized crop, identified potential end uses, and assessed nutritional impacts.



“If a by-product is called waste, it is considered waste. If it called a raw material, it is considered a raw material.”

Roundtable participant

**\*Upcycled Foods.** Upcycled foods use ingredients that otherwise would not have gone to human consumption, are procured and produced using verifiable supply chains, and have a positive impact on the environment (19). Upcycled foods and ingredients are sourced from a variety of novel side streams, tapping into the latent nutrition value they hold. Because of source variety, upcycled foods and ingredients must be evaluated and assessed before going to market. Considerations that must be made when producing upcycled foods and ingredients include safety, physical properties, labeling, consumer acceptability, cost, availability, and whether the food or ingredient supports the overall mission of valorizing food side streams without doing more harm than good.

The Upcycled Food Association (UFA) has made progress in setting standards for food processing side streams and requires five principles when designating upcycled foods:

- They are made from ingredients that would otherwise have gone to a food waste destination
- They are value-added products
- They are intended for human consumption
- They have an auditable supply chain
- They have labels indicating which ingredients are upcycled

As demand grows for upcycled products, securing a steady supply of upcycled foods and ingredients that are safe and economical in the supply chain is required (Industrial Application of Upcycled Foods Case Study 1). Communication between suppliers and processors helps to predict and plan for year-to-year variation in raw product, which helps with ensuring accurate planning and inventory to help mitigate food loss. Finally, the environmental impact and sustainability of these novel foods and ingredients must be assessed (e.g., **\*Lifecycle analysis**) to ensure that the overall mission and vision of mitigating food loss and waste is met without unintended consequences that cause more harm than good to the food system, such as increasing carbon footprint of a material as a result of transportation. Stakeholders are faced with containing costs and communicating value for upcycled foods to meet their full potential (Industrial Application of Upcycled Foods Case Study 2). With all of these considerations, it would be beneficial for food scientists to have a systematic way of evaluating current food processing side streams to determine the feasibility for use as value-added ingredients for upcycled foods.

**\*Upcycled Foods:** A food that uses ingredients that otherwise would not have gone to human consumption, is procured and produced using verifiable supply chains, and has a positive impact on the environment

**\*Lifecycle Analysis:** The process of evaluating the effects that a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities

## Case Study

### Industrial Application of Upcycled Foods Case Study 1:

#### Developing a Novel Food Product Using Upcycled Ingredients

A manufacturer was looking to create a smoothie using upcycled produce. There were several challenges to overcome when formulating the smoothie. Produce, particularly produce formerly considered waste, is inherently unstable. Bearing this in mind, responsibility for the food safety of the ingredient had to be established. Was it on the supplier of the produce or on the company utilizing it as an upcycled ingredient? Further, the volume and availability of produce may be volatile from year-to-year. As for formulation specifics, produce utilized as an upcycled ingredient may not meet specification criteria such as size, color, and shape. Finally, the manufacturer ensure that the ingredient supported the overall mission and value proposition for use of an upcycled ingredient in terms of environmental, societal, and economic impacts.

To formulate the smoothie using upcycled produce, the manufacturer had to work with producers to harvest imperfect and surplus produce and find a supplier that already provided upcycled ingredients to help predict better year-to-year forecasting. Partner relationships between suppliers and developers were created to invest and ensure food safety of the upcycled produce. Supply chain and formulation were adapted to the uncommon ingredients utilizing a backward-development approach. First, the estimated total volume of the upcycled produce was estimated. Then the amount of the ingredient available to produce the product was determined. The maximum percentage of ingredient needed to include in the formulation to meet total product demand was determined to set a threshold for the ingredient. Formulation included steps to address potential variation in ingredients, for example chopping and pureeing to eliminate size differences, and blending batches for consistency, while still delivering the desired texture, color, and taste of the final product. This formulation required educating the quality assurance team on accepting variance in specifications and adopting by the processing team, when possible, to accommodate these variations. Evaluation of critical control points in processing helped to assure the safety of the final product. A final assessment of the environmental and socioeconomic impacts of utilizing the upcycled produce in the smoothie ensured it met the manufacturer's needs.

The key take-aways from this case study was the importance of partnerships between producers and suppliers to ensure the safety of the ingredient and help with year-to-year forecasting. The backwards development approach that set a threshold for upcycled ingredients helped to ensure demand. Flexibility and collaboration were required from the supply-chain, development, quality, and processing teams. Flexible processing options, such as to account for size variation, allowed for more variability in ingredients, but the teams had to have strong communication to build that flexibility. The upcycled ingredients resulted in positive environmental and socioeconomic impacts, but only when the unintended consequences of their use were considered and accounted for.



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## **Technologies that ensure the safety and affordability of value-added ingredients from food processing side streams**

Utilizing technologies to ensure the food safety of valorized side streams, to remove physiochemical contaminants and pathogenic bacteria detrimental to human health, is essential. Since each novel side stream and source presents various food safety risks, individual assessments must be made, which can be costly and time consuming. Food safety evaluations that account for physical properties, varying stabilities, and processes are of the utmost importance to ensure safety from physiochemical contaminants, pathogenic bacteria, toxins, and carcinogens.

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## **Communications with consumers the impact of food loss and waste and the benefits of foods made from upcycled ingredients**

The promise of upcycled foods to contributing value to food system, reducing impacts on environmental sustainability, improving food security, and mitigating food loss and waste can be recognized only if consumers are willing to purchase and consume them. A recent survey of US consumers indicated that demand for upcycled foods has rapidly increased since 2019: 95% of consumers indicated they wanted to do their part to reduce food waste and 57% indicated they intended to specifically buy more upcycled foods (Mattson).

In addition to hedonic considerations, there are cost considerations to utilizing upcycled ingredients. Whereas upcycled foods may ultimately be a value-add to the food industry, they may include additional processing that requires investment. Unless upcycled foods can be produced for the same price of other foods, communicating the value of upcycled foods to consumers will be of importance. A 2021 report by INNOVA Market Insights indicated 62% of US consumers were willing to pay more for products that prevent food waste. The additional processing that side streams typically require to achieve the taste and performance that meet consumer demand, however, may contrast with current consumer trends for minimally processed foods. Therefore, consumer education and transparent marketing and communications will be essential to build consumer trust and acceptance of valorized ingredients and upcycled foods.

## Case Study

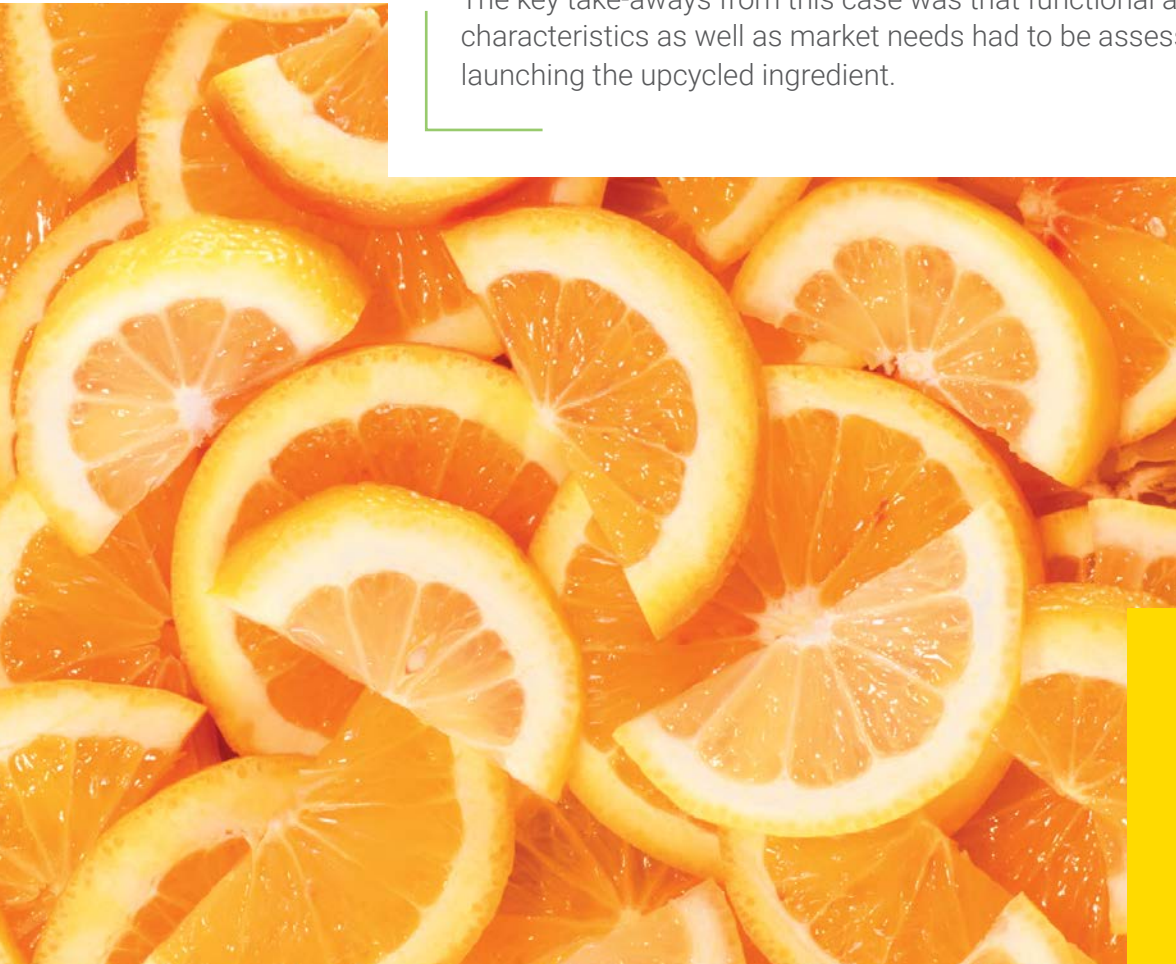
### Industrial Application of Upcycled Foods Case Study 2:

#### **Valorizing a food processing side stream by determining use as an upcycled ingredient**

A manufacturer was looking to valorize a food processing side stream to produce an industrial ingredient. This presented several challenges, which included performing several product development tests to better understanding the functionality and use for the upcycled ingredient as well as assessing its safety in different applications.

To valorize the side stream for use as an upcycled ingredient the team conducted a technical assessment of the ingredient to help develop a strategy for best use and marketing purposes. Applications were developed, and a test plan was launched for the ingredient. A competitive review against other ingredients already on the market was conducted to understand the strengths, opportunities, and weaknesses associated with its sale and use.

The key take-aways from this case was that functional and hedonic characteristics as well as market needs had to be assessed before launching the upcycled ingredient.





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## **Investment in scalable and affordable food science and technology innovations in developed and developing countries to reduce food loss**

Substantial investment in food science and technology research and innovation is crucial to creating solutions for mitigating food loss in the middle segment. Differences in processing capabilities in developed and developing countries mean that solutions to minimize or valorize food losses may look different around the globe. Investing in models that bring food science and technology solutions to the marketplace in a timely manner is critical. Furthermore, these models must be simultaneously cost effective and have the potential to increase the nutrient density of food, to help improve nutrition in developing markets (Applied Research Study 2).



## Case Study

### Industrial Application of Upcycled Foods Case Study 1:

#### **Adding Value to Low-Fat Soy Cake in Sub-Saharan Africa**

In Sub-Saharan Africa (SSA) soybean oil is mostly extracted using expellers. The soy cake obtained from this process is highly nutritious. Despite its wide use for livestock feeding applications, it has a reduced shelf life due to the oxidation of remaining oil. Soy cake can be used for human nutrition in SSA, as is the case in the USA, but increasing its value faces many challenges, including limited resources for processing.

Researchers were tasked with creating a soy protein concentrate from low-fat soy cake obtained from oil expellers. The challenges associated with this task included the limited utilization of soy protein concentration in SSA mainly due to inadequate processing capabilities, high processing costs, and the complexity of current processing techniques. Further soy protein concentrate inclusion into food products has to be technically and economically feasible for companies to adopt the processing technology.

To overcome this challenge, a less expensive processing method, initially developed by Dr. Keshun Liu at the USDA, was evaluated to prepare soy protein concentrate in SSA in collaboration with partners at the National Agricultural Research Organization from the Ugandan Government. The process uses water to wash a significant amount of oil, oxidized oil, oligosaccharides, and phytates away from the cake, and the slurry is dried before milling and use, meaning no solvents and desolventizing steps are needed, reducing the processing cost. Further, less remaining oil and less oxidized oil represents an increase in shelf life. The protein (~63-65%) has increased quality and digestibility, and more protein offers an opportunity to enhance the final protein content with lower addition. Finally, less phytic acid means potentially improved micronutrient absorption (e.g., iron, calcium, zinc). Most importantly, the process can be accomplished using resources available in SSA.

The key take-aways from this applied research was that a bottom-up approach to upcycling low-fat soy flour with considerable input and interaction between partners in SSA and USA was feasible. Shelf-life was enhanced due to the washing step. Protein content, quality, and digestibility were increased, making it an adequate ingredient to blend with foods for vulnerable groups indicating that low-fat soy cake can obtain a higher value in the market, thereby improving the value chain. Future efforts are focused on value-added uses for the water used in the washing process.



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## Enhanced food preservation with scalable, affordable technology

**Innovative Packaging.** Packaging, a key driver in food loss and waste, is designed to protect the quality of food and help ensure its safety for consumption (20). Sustainable innovative packaging technologies can help mitigate food loss and waste, such as active and intelligent packaging technology that can record internal and external environmental conditions to help prevent loss and waste from spoilage and other quality degradation by extending shelf-life and compostable packaging that can help mitigate environmental impacts when food loss and waste cannot be prevented (21). It should be noted, however, that premature degradation of compostable packaging has the potential to create more food loss and waste, and thus careful examination of packaging materials for targeted design is of importance. Novel packaging designed to replace traditional materials such as plastics, coatings, and cardboard can help at both ends of the food value chain by utilizing side streams for edible and biodegradable packaging production and reducing waste after use (21). Whereas research on novel packaging is ongoing, investment from public and private sectors that can speed innovation and adoption of such technologies is warranted.

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## Collaborations across the food supply chain to ensure the sustainability and feasibility of technologies to reduce or valorize food loss

A shift from research, education and outreach funded and executed by government and university partners is the development of innovation hubs created with public and private collaboration and investment from industry, academic, government, and non-government investors. Innovation hubs utilize transdisciplinary quantitative and qualitative research to focus on swift technology development and implementation that addresses a system of systems and can reduce food loss and waste and enhance food security. Innovation hubs can also be effective food safety hubs that assess and address the potential pitfalls that stem from innovation. As food by-product streams have multiple potential uses, such transdisciplinary efforts could include materials/packaging engineers, nutritionists (to assess impacts of bioactive extracts), economic/life cycle analysis experts, microbiologists, toxicologists, agronomists, and others to complement the work of food and technology scientists.

# CALL TO ACTION

The goal of the roundtable was to identify solutions from food science and technology that are needed to reduce food loss and valorize food processing side streams. During the roundtable it became evident that food science and technology must be considered in policy making around food waste and loss and coordinated approaches are necessary to ensure efficiency and impact of measures. Participants made the following recommendations:

- Quantify the true value of food
- Build and strengthen cross-functional coalitions across the food supply chain
- Map and track food loss and waste
- Invest in processing and scaling innovation
- Expand food policies to include valorization of food loss

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## Quantify the true value of food

Traditionally, the value of food has been measured by cost and convenience and currently there are not enough financial incentives to mitigate food loss and waste. A consideration of the total socioeconomic and ecological cost of food that can be quantified through cost-benefit analyses and communicated with consumers is necessary to shift societal values and increase consumer demand that will ultimately drive investment in food science and technology solutions that reduce food loss and waste. The value of co-products and by-products must be quantified and recognized for organizations to adopt practices for valorizing food processing side streams. Costs of food losses can be different from one location to another and borne by different actors, so local and/or other relevant impacts need to be assessed.

A systematic approach to evaluating food processes to determine the potential of upcycling side streams would be instrumental in establishing the true value of food and could include factors such as:

- Annual amount and geographical location of potential upcycled ingredient that is produced
- Utilization of the ingredient
- Cultural perceptions of use as an upcycled ingredient
- Value of the ingredient category (e.g., protein, fiber, carbohydrate)
- Relevant material characteristics

Once food processing side streams are established and ranked, they can be assessed for specific challenges and systematically screened for use as upcycled ingredients. It is also critical to support food science, technology, and engineering research and innovation to create solutions that allow for food processing side streams to become safe raw materials.

The lifecycle assessment is a promising model that has been demonstrated useful to help determine the true environmental impact of minimizing or valorizing waste. This could be helpful to ensure there is a positive impact on sustainability with new processes and upcycled ingredients.

Another model useful for identifying critical points for investment is the Hazard Analysis and Critical Control Points (HACCP) model, utilized to prevent foodborne illness. The HACCP model, in which critical control points are identified, managed, and assessed could be utilized for similar assessment of critical points of loss that can be targeted and monitored for mitigation efforts.

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## **Build and strengthen cross-functional coalitions across the food supply chain**

Bringing together all sectors of the food supply chain is critical for establishing long-term sustainable solutions to minimize or valorize food loss. Partners should include, but not be limited to: industry, academia, government and consumers, as well as agronomists, food scientists, engineers, nutritionists, animal scientists, microbiologists, toxicologists, and many others. Data collection and sharing among these stakeholders is critical to increase transparency and accountability to build trust around efforts to mitigate food loss.

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## **Map and track food loss and waste**

Efforts that include central databases for measuring, setting research goals, and connecting with industry is a public-private partnership opportunity vital to ensuring that funding and research is usable and useful to the industry that constitutes our food system. Ensuring alignment across the food industry and with the FAO will be critical to success. Further, creating an industry resource that one can search for solutions that fit individual business needs but consider the greater food system is good for business and good for waste. It could also help with supply chain stability concerns and help make upcycling desirable, because companies would be able to find foods and ingredients where they are already being produced, instead of relying on distant suppliers. Such a system could also encourage transparency and communication across the value chain.

Digitization of the food system can provide a platform for interconnected and interrelated systems and processes and has been proposed as a solution to improving communication across the value chain. Open access supply-chain data available to all stakeholders in industry, government, and consumer markets could allow for centralized data collection and sharing, improvement and optimization across the food system, and real-time supply-chain transparency that would improve communication, collaboration, and transparency across the value chain. Whereas digitization of the food system is possible, it requires substantial investment and coordination from public and private sectors.

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## **Invest in processing and scaling innovation**

Investment in processing and scaling innovation that would allow for increased contract and modular processing set up for size variations in side streams would improve yield and recovery of ingredients from the manufacturing process and could help with mitigating food loss. Further, in the global food economy in which we live, providing access to current technologies is necessary for developing countries to contribute to solutions aimed at mitigating food loss.

Coordination between research and development and supply chain teams that account for and accommodate the volatility of availability of upcycled ingredients from year to year is vital to reducing food loss. Workforce training that can aid research and development and quality assurance teams in formulating and assessing for potential variations in ingredient color, size, and shape to accommodate upcycled ingredients is necessary to expanding the valorization of food processing side streams.

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## **Expand food policies to include valorization of food loss**

Policy that incentivizes industry toward a circular economy through adequate measurement and tracking of ingredients is necessary to advance efforts to valorize food processing side streams and mitigate food loss. Currently, the US has national goals and initiatives aimed at reducing food loss and waste, but without policies, incentives, and enforcement in place, progress is slow, uncoordinated, and inefficient.

# Conclusion

There are many challenges, opportunities, and solutions to valorizing food processing side streams in the middle segment as identified at the IFT virtual roundtable, “Food Science & Technology Solutions for Reducing Food Waste and Valorizing Waste Streams”. Support for research and innovation in food science and technology solutions for developing new products from food processing side streams, evaluating the safety of valorized side streams, and increasing the technology available to preserve food is necessary to mitigate food loss from the middle segment. Ultimately strengthening coordinated efforts among public and private sectors, allocating resources dedicated to food science and technology solutions, and legislative action are necessary to meeting global targets to reducing food loss and waste while feeding the world.



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