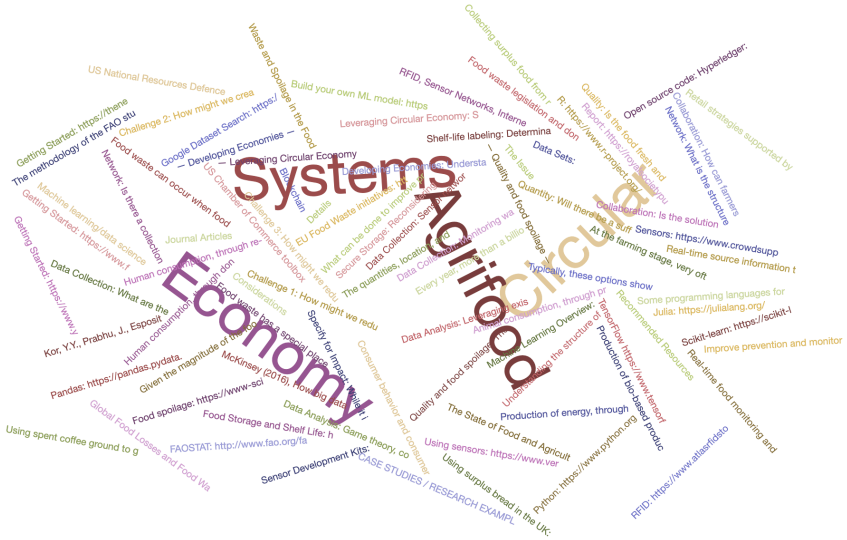
CIDA Hackathon: Theme 4

Circular Agrifood Systems and Economy



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The Issue

Every year, more than a billion tons of food is wasted worldwide. This represents about 30% of the total production and presents a great economic loss for the society as well as a negative environmental externality. This wastage occurs in all countries (developed as well as developing), in all food products (e.g. cereals, meat, fish and seafood, milk, eggs, oilseeds and pulses), and at all stages of the supply chain (production, transportation, processing, and retail). While food waste occurs due to a wide variety of reasons (e.g. lack of cosmetic appeal, spoilage, quality defects, supply chain inefficiencies), food safety per se is actually is not a major driver of food waste, except for the fact that many consumers do not differentiate between food spoilage and safety, and may discard food that is past a “best by” or “sell by” date because they incorrectly assume the food is unsafe. While it is convenient to blame the consumer, Food and Agriculture Organization (FAO) estimates that about 40% of the food waste occurs away from the consumer. The reasons could be (i) timely unavailability of labor and other resources during harvesting; (ii) discarding of “ugly” food for minor cosmetic blemishes; (iii) transportation delays and failures; and (iv) retailers over-ordering make their shelves visually appealing.

Given the magnitude of the food waste problem, in order to develop effective tools to reduce waste, it is necessary to segment the problem along many of these dimensions. We propose a few directions, but many others are possible and should be considered.

Challenge 1: How might we reduce food waste by better managing the existing (linear) systems?

Challenge 2: How might we create idealized circular economy solutions for food waste? Can we identify alternative uses for food losses and waste? How might we build interactions with non-food industries?

Challenge 3: How might we reduce food waste at the farm level in developing economies?

Details

Quality and food spoilage: The focus of this challenge is to design a project that utilizes technology and/or improved implementation of traditional approaches (e.g. fermentation) to reduce food waste. You may want to restrict your project to certain foods, such as meats, lettuce, grains, etc. Pay attention to the time horizon (e.g. hourly, daily, monthly, yearly) over which you are trying to solve this problem.

Food waste can occur when foods change due to chemical reactions or the action of microbes that make the food unappealing to consumers (for example, coagulation of milk; browning and discoloration of produce). Best-by, Use-by, and Sell-by dates are typically designed to assure customers purchase and consume the best quality products, but are often mis-interpreted by consumers as indicating the limits of safety of a product, which has been proposed to lead to on-necessary disposal of foods.

Understanding the structure of the food supply chain, identifying potential location and processes, which are susceptible to contamination, developing tools to reduce the risk of pathogen or microbial intrusion, and building systems to quickly and accurately identify and destroy contaminated food.

Leveraging Circular Economy: In situations in which food waste cannot be reduced or eliminated, it is necessary to look for ways in which it can be reused or repurposed, thus providing value to society. The main concept driving such initiatives is the transition towards a more circular economy, which aims to lower resource consumption by a combination of reduce and reuse options. Among other organizations, we see governmental organizations focus on the issue, such as the recent development of a circular economy toolbox by the US Chamber of

Commerce and the action plan dedicated to the circular economy by the European Union. But non-governmental organizations and businesses also play an important role.

Food waste has a special place in the circular economy. Imagine, for instance:

- Human consumption, through donation to food banks, food pantries, soup kitchens, or some other way to get the products consumers
- Human consumption, through re-processing food products before spoilage or after spoilage has occurred
- Animal consumption, through processing food waste or byproducts into animal feed
- Production of bio-based products, through processing food waste or byproducts (e.g. extraction of biochemicals or food ingredients through biorefining specific organic waste streams)
- Production of energy, through biogas production or incineration.

Typically, these options show some hierarchy of preferences, where some options maintain more value than others (from top to bottom in the list above). For many food waste streams, it is possible to identify a way to reduce or reuse, but there are often many technological and economic challenges: is it feasible to use some advanced processing technology on a low-value waste stream? Is it possible to collect specific (perishable) waste streams in an efficient way? If I make a product from a waste stream, do I then suddenly need a stable waste stream to keep my customers happy?

Developing Economies: Understand the specific challenges faced by developing economies in the domain of food waste, develop tools and methods to help them combat food waste and enable their populations to achieve affordable, nutritious, and healthy food consumption. Losses in the food supply chain manifest themselves very differently in developing economies. The most important difference being that in developing economies, food waste is more prevalent in the upstream stages (e.g. at the farm, in the distribution, at the market) of the supply chain and not so common at the downstream stages (e.g. retailers, consumers).

At the farming stage, very often the crop is wasted because of inadequate water, fertilizer, or weeding processes. Once the crop is harvested and in the distribution system, lack of adequate transportation equipment, climate-controlled storage facilities, and even road infrastructure result in spoilage and food waste. Once the food reaches the market, inefficiencies and delays in transaction result in food getting spoilt and subsequent wastage.

The quantities, location, and the causes of food waste in developing economies are very different from that in developed countries. As a result, solutions, strategies and policies should be customized for developing economies.

What can be done to improve productivity at the farm level focusing on irrigation, fertilizer application, and effective weeding strategies? Technology development and deployment for climate-controlled storage facilities (appropriate for low resource locations with unreliable or non-existent electricity infrastructure) would be another dimension to explore. Methods for appropriate and adequate packaging could help battle food waste. Tools and systems to make food move quickly through the market would be another excellent opportunity to explore.

Considerations

— Quality and food spoilage —

- **Quantity**: Will there be a sufficient supply of food (and in particular, how much food is wasted and what are the reasons for waste)?
- **Quality**: Is the food fresh and has the nutritional value indicated on the label?

- **Consumer behavior and consumer acceptance**: Consumer behavior (e.g., proper food storage, appropriate purchasing behavior) as well as appropriate consumer use and understanding of labelling dates (Use-by, Sell-by, Best-by) play an important role in reducing food waste that have been difficult to address. In addition, consumer acceptance of new technologies that reduce food waste is essential to assure a positive impact of these new technologies.
- **Shelf-life labeling**: Determination of appropriate shelf life dates that convey accurate and reliable information (despite considerable differences in food storage conditions between containers produced at the same time, but distributed through different stores and to different consumers) remains a major challenge, particularly since technology solutions (e.g., time temperature indicators) are often cost-prohibitive due to the ROI per unit of food.
- **Data Collection**: Sensor networks (video, temperature, etc.), drones, and other Internet-of-Things devices, to monitor the food supply chain from production to consumption.
- **Data Analysis**: Leveraging existing tech and/or machine learning tools to analyze data and predict product shelf life and risk of spoilage. Software tools for this task include R, Python, Julia (programming languages), Scikit-learn, Pandas, and TensorFlow/PyTorch (machine learning/data science frameworks). Algorithmic tools for this task include supervised learning (e.g. for predicting food waste based on sensor data), linear and convex programming (e.g. deciding how to allocate spoilage/loss-detection resources within a food system), and time-series analysis (e.g. using past data to predict and possibly avoid future waste).
- **Secure Storage**: Reconsidering how food is managed, tracked or documented; looking at blockchain for tamper-proof evidence of events, storage of contracts, to fight food-related fraud events

— Leveraging Circular Economy —

- **Network:** Is there a collection, processing, and distribution network? Is it a local initiative? Is there sufficient scale to make the reuse feasible from a business perspective? How is the waste transported?
- **Collaboration:** Is the solution spanning different stakeholders in the supply chain? How is the collaboration organized? Is there a coordinator or facilitator (physical or online)? How are costs and benefits shared among the stakeholders? Are the right incentives in place to make it work?
- **Data Collection:** Monitoring waste at specific locations in the food supply chain might be required to be able to valorize the waste streams efficiently and effectively. This can be done automatically with Internet-of-things devices, sensor networks, or by monitoring streams of digital information that already exist within the food distribution chain.
- **Specify for Impact:** While it is important to reduce food waste throughout the supply chain, it may be helpful to focus on a specific part of the chain, such as retail environments, food-processing industries, food service locations, hotels, etc. You could also restrict your project to certain specific food waste streams, such as 'ugly' fruits, surplus bread, spent coffee grounds, orange peels, etc.

— Developing Economies —

- **Network:** What is the structure of a typical supply chain in a developing economy? Where are the main pain points in terms of food waste? What can be done to alleviate them?

- **Collaboration:** How can farmers, traders, distributors, processors, retailers and consumers work together to reduce food waste? What can policymakers do encourage, support and incentivize this collaboration? What tools can be developed and implemented to ease such collaboration?
- **Data Collection:** What are the incentives driving the various stakeholders in the various stages of the food supply chains in developing economies?
- **Data Analysis:** Game theory, contract design, artificial intelligence, and machine learning can potentially be used to reduce food waste in developing economies. For example, we could develop a mathematical model for food waste based on game theory, and design incentives that adjust the Nash equilibrium in a way that wastes less food.

Recommended Resources

Journal Articles

- The State of Food and Agriculture 2019 - Moving forward on food loss and waste reduction: http://www.fao.org/documents/card/en/c/ca6030en
- *Waste and Spoilage in the Food Chain*: https://www.rockefellerfoundation.org/report/waste-and-spoilage-in-the-food-chain/
- Food waste reduction: http://www.fao.org/save-food/resources/keyfindings/en/
- EU Food Waste initiatives: https://ec.europa.eu/food/safety/food_waste_en; ZeroW - Innovations for Zero Food Loss & Waste (zerow-project.eu); D1.1 Conceptual framework for food loss and waste (zerow-project.eu)
- US National Resources Defence Council: https://www.nrdc.org/issues/food-waste
- Kor, Y.Y., Prabhu, J., Esposito, M. (2017). "How Large Food Retailers Can Help Solve the Food Waste Crisis", Harvard Business Review, December 2017, https://hbr.org/2017/12/how-large-food-retailers-can-help-solve-the-food-waste-crisis
- McKinsey (2016), How big data will revolutionize the global food chain: https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/how-big-data-will-revolutionize-the-global-food-chain
- Food waste legislation and donation in Europe: https://www.euronews.com/2019/02/06/how-is-food-waste-regulated-in-europe
- US Chamber of Commerce toolbox, https://www.uschamberfoundation.org/circular-economy-toolbox
- *Food spoilage*: https://www-sciencedirect-com.proxy.library.cornell.edu/book/9781845697013/food-and-beverage-stability-and-shelf-life
- *Food waste reduction*: http://www.fao.org/save-food/resources/en/
- *Food Storage and Shelf Life:* https://www.ift.org/career-development/learn-about-food-science/food-facts/food-storage-and-shelf-life
- *Using sensors*: https://www.verizon.com/about/sites/default/files/humanability/iot-food-supply-chain.html
- Global Food Losses and Food Waste http://www.madr.ro/docs/ind-alimentara/risipa_alimentara/presentation_food_waste.pdf

- The methodology of the FAO study: “Global Food Losses and Food Waste - extent, causes and prevention”- FAO, 2011 http://www.diva-portal.org/smash/get/diva2:944159/FULLTEXT01.pdf
- **Data Sets:**
    - *Google Dataset Search*: https://toolbox.google.com/datasetsearch
    - FAOSTAT: http://www.fao.org/faostat/en/#home
- **Machine Learning Overview:**
    - *Getting Started*: https://thenewstack.io/machine-learning-made-easy/
    - *Build your own ML model*: https://ai.google/tools/
- **Some programming languages for machine learning and data science**
    - Python: https://www.python.org/ (general purpose language, most common one used for ML)
    - R: https://www.r-project.org/ (powerful statistical computing language)
    - Julia: https://julialang.org/ (scientific computing language; less popular than python)
- **Machine learning/data science frameworks/toolkits**
    - Scikit-learn: https://scikit-learn.org/ (general machine learning toolkit, has most basic ML models)
    - Pandas: https://pandas.pydata.org/ (powerful library for managing and analyzing data)
    - TensorFlow https://www.tensorflow.org/ and PyTorch https://pytorch.org/ (deep learning libraries; especially good for training computer vision models; PyTorch seems more popular at the moment)

Blockchain

- *Getting Started*: https://www.forbes.com/sites/jennysplitter/2018/09/30/what-can-blockchain-really-do-for-the-food-industry/#2d4df89e488e
    - *Open source code*: Hyperledger: https://www.hyperledger.org

RFID, Sensor Networks, Internet-of-Things, Drones

- *Getting Started:* https://www.youtube.com/watch?v=1-RGGH78I4k
- *Report*: https://royalsocietypublishing.org/doi/10.1098/rsta.2013.0313

Sensor Development Kits:

- Sensors: https://www.crowdsupply.com/development-kits
- RFID: https://www.atlasrfidstore.com/rfid-development-kits/

CASE STUDIES / RESEARCH EXAMPLES:

- Using surplus bread in the UK: https://www.theguardian.com/environment/2019/jul/06/making-a-crust-tesco-to-use-unsold-bread-in-new-products
- Using spent coffee ground to grow mushrooms or make textile fibers (many examples available through a simple internet search)
- Collecting surplus food from retail or foodservice through the Too Good To Go app: https://www.toogoodtogo.com/en-us (starting 2020 in the US)

- Retail strategies supported by Wasteless, a company working on AI-powered dynamic pricing strategies: https://www.wasteless.com/
- *Real-time food monitoring and notification*: The fridge, through the use of RFID tags, could provide the user with information about food that needs to be consumed before it shows quality degradation and spoils.
- *Real-time source information to consumers*. Consumers could scan a QR code on products in a store and immediately retrieve information about the farm where the item was produced, where it was stored and for how long, etc. The information could be stored reliable, and retrieved from a blockchain. The blockchain would also store all transactions between various stages in the food supply chain. https://www.ripe.io/
- *Improve prevention and monitoring of food contamination along the food production chain*. Decision support tools are needed to help food producers, processors and retailers predict the risk of spoilage and contamination with spoilage organisms and make better decisions in selecting and implementing appropriate strategies that reduce spoilage.