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REDUCTION OF FOOD LOSS AND WASTE

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Reduction of Food Loss and Waste

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The Proceedings of the Conference on

Reduction of Food Loss and Waste

11-12 November 2019

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Joachim von Braun
Marcelo Sánchez Sorondo
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"Fighting against the terrible scourge of hunger means also fighting waste. Waste reveals an indifference towards things and towards those who go without. Wastefulness is the crudest form of discarding. I think of the moment when Jesus, after the distribution of the loaves to the crowd, asks for the scraps to be gathered up, so that nothing would go to waste (cf. Jn 6:12). Gathering in order to redistribute; not production that leads to waste. To throw food away means to throw people away. It is scandalous today not to notice how precious food is as a good, and how so much good ends up so badly".

Address of His Holiness Pope Francis to Members of the European Food Banks Federation, Consistory Hall, Saturday, 18 May 2019.


D.E. VIGANO
J. VOS BRAUN
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Joachim von Braun, Marcelo Sánchez Sorondo and Roy Steiner

Introduction

The global food system is malfunctioning, leaving large segments of the population undernourished or malnourished, and causing large environmental damage. Food losses in the production, processing and marketing parts of the food systems are part of the problem. Food wasting at the retail, household and restaurant levels is a serious problem too. The analyses and calls for action in this volume are motivated by the United Nations Sustainable Development Goal (SDG) No. 12, i.e. Ensuring sustainable consumption and production patterns, and specifically, "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".

This goal is very much in line with the Encyclical *Laudato Si'*, where Pope Francis calls for changes to overcome the "throwaway culture". Food Loss and Waste (FLAW) is a moral issue because of the adverse effects on people and our planet. It is detrimental to the planet due to greenhouse gas emissions and the wasting of the water and land used as inputs, and to people – the poor in particular – whose labor is squandered and whose livelihoods are compromised when FLAW occurs.

Box 1: SDG 12 – ENSURING SUSTAINABLE CONSUMPTION AND PRODUCTION PATTERNS
"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". Since loss and waste are related but distinct phenomena, each may merit a unique indicator, as stated by FAO:
Sub-Indicator | Food Loss Index: The Food Loss Index (FLI) focuses on food losses that occur from production up to (and not including) the retail level.
Sub-Indicator | Food Waste Index: A proposal for measuring Food Waste, which comprises retail and consumption levels, is under consideration. Clarity on content of these indicators could be helpful to measure and guide actions.

Source: http://www.fao.org/sustainable-development-goals/indicators/1231/en/

An aim of this conference and its proceedings volume is to reach different but complementary communities that can broaden the alliance needed to address the challenge of food loss and waste. Key objectives are to share the latest scientific evidence on how to reduce food loss and waste and thereby contribute to global food and nutrition security. Secondly, to provide recommendations for expanded global and national actions, including public and private investments and initiatives by citizens, corporations, governments, and international organizations. Moreover, the alliance of actors must become broader to make significant improvements globally in reducing FLAW.

To fulfil these objectives, we focus on clearly defining food loss and waste, while adopting a value-chain approach. When considering the magnitude of the food loss and waste challenge, summing up the tonnage of different foods is not appropriate; not only weight but the economic and environmental cost of wasted and lost food must be considered. The latest approaches to measurement in economic, caloric, or quality-adjusted weight terms are presented and discussed.

Further, food loss and waste reduction has huge benefits but also costs and these costs must not be ignored when aiming for efficient solutions. Benefits and costs must consider environmental as well as food and nutrition security effects. We know that environmental change and people's health cannot be easily captured by economic calculations.

Successfully meeting SDG 12.3 requires approaches that foster education and awareness, behavioral change, a renewed global dialogue, and coordinated global action. Ultimately, we need to create incentives that will strengthen the business case to tackle food loss and waste and move to more sustainable consumption patterns.

As we aim to unite and improve our understanding and strengthen our conviction to act on food loss, we are aware that these phenomena are embedded within a broader food systems context. The plan put forward by the UN Secretary-General to hold a Food Systems Summit in 2021 will provide an opportunity to translate global goals into actions for FLAW reductions.

It is encouraging that actions to reduce food loss and waste are already planned or in place in many countries, but so far do not add up to sufficient global impact and joint learning. The most promising actions can and must be enhanced. By bringing together a group of prominent leaders, actively engaged with this issue, from academia, religious communities, private sector, government, civil society, and the United Nations (UN), we

aim to create an interdisciplinary space for analysis, sharing of knowledge and focused solutions. Ultimately, reducing FLAW requires a change in mindsets among those who waste food and large-scale investments in value chains that are losing food. How to go about these challenges is emphasized in the chapters of this volume and summarized in the statement on conclusions and proposed actions.

Conclusions and Proposed Actions (Conference Statement)

1. Motivation of the conference

In the Encyclical *Laudato Si'* Pope Francis calls for global changes to overcome the "throwaway culture". A representation of this culture is Food Loss and Waste (FLAW), which has serious moral repercussions, in view of the prevailing hunger of more than 820 million people and lack of access to healthy diets by 2 billion people (FAO's SOFI report 2019). Resources such as water and fertile land are becoming scarcer because food is produced but never eaten.

FLAW significantly contributes to greenhouse gas emissions (SOFA 2019) and thereby to climate change and its consequences. FLAW is detrimental to the planet and its people. It is morally, economically and environmentally unacceptable in the era of the Sustainable Development Goals (SDGs). We call on our leaders, and on all of us, for increased commitment to action toward SDG 12.3, i.e. by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including postharvest losses – an achievable goal based on existing knowledge and technology. Yet, even though it is within our ability to tackle, FLAW reduction needs more attention and investment.

Successfully achieving Target 12.3 of the United Nations SDGs requires a new perspective on how to reduce the use of resources and increase the efficiency of the production, preservation, processing and distribution of food at the producer, intermediary, processor and wholesale level (i.e. losses in the value chain). It also requires addressing our "throwaway culture". For that, education, awareness, and behavioral change among consumers and retailers, are critical. Our conference therefore calls for renewed global dialogue at the highest levels of government, business, religion, and civil society to achieve the target of halving FLAW by 2030.

2. Objectives of the conference

The conference took note of new reports on FLAW problems, such as the State of Food and Agriculture Report (2019) by the Food and Agri-

culture Organization (FAO) of the United Nations, and Reducing Food Loss and Waste: Setting a Global Action Agenda (2019) by World Resource Institute (WRI) and a coalition of partners. The findings of these, and other reports, provide a basis for action.

The three key objectives of the conference were to:

1) Share the latest scientific evidence on how to reduce FLAW and thereby contribute to a more sustainable and inclusive global food system;
2) Provide recommendations for expanded global and national actions, including public and private investments and initiatives for citizens, the private sector, governments, and multilateral organizations; and
3) Broaden the alliance of actors to make more significant improvements in reducing FLAW.

3. Localizing the FLAW problem, while tapping into global solutions

Data deficiencies mask the diversity of the FLAW problem – which varies greatly across regions and value chains. While a high percentage of food is currently lost at production, handling and processing stages in low-income and emerging economies, food is wasted in retail and consumption stages in higher income countries due to market design and consumer behavior. Yet market design and food waste patterns are increasing in low- and middle-income countries as the global middle class grows and urbanizes. Solutions are within reach for all country groups, but will need to be tailored to each specific context, and differentiated by food loss versus food waste as these are related but distinct concepts. Food waste happens due to lack of appropriate infrastructure, regulations, profit-seeking, and negligence, time scarcity and economic abundance at the consumer level. Food loss occurs due to unfavorable climatic conditions, improper post-harvest handling, and incentive structures leading to food loss as a rational economic option, as well as lack of information, education, technology, infrastructure, affordable financing and market access. FLAW has social equity and gender implications. Food production, not only in low-income countries, involves large shares of women's unpaid labor and often low-paid workers, including migrants, producing cheap food that might be undervalued and thus wasted by customers. In addition, all steps in supply chains should be reviewed and monitored in order to prevent the use of forced labor and modern slavery (according to SDG 8.7).

Value chains of perishable and nutrient-rich foods (both crops and animal-sourced protein) are significantly affected. More nutritious and healthier dietary patterns require managing and preserving these nutritious foods and attention to food safety (as addressed in the Conference by

the Pontifical Academy of Sciences and the Global Alliance for Improved Nutrition on Food Safety and Healthy Diets in 2018).

FLAW requires our attention along with all aspects of wasteful processing, transportation, packaging (e.g. the plastics issue) and energy usage along food supply chains – issues that a circular economy and bioeconomy are trying to address systemically. Attention to prevention, not just reduction, should be considered, and solutions need to consider further the possible impacts on food access and affordability.

4. Strengthening of information and data

Only when sound data are gathered and made available, measurement and monitoring progress against benchmarks becomes feasible and viable for investors and companies. When considering the magnitude of the FLAW challenge, summing up the tonnage of different foods does not appropriately capture food, environmental, and economic issues. We must move beyond a weight metric and assess the economic, environmental, institutional, health, and human costs of lost and wasted food. The hotspots in value chains where food losses occur are increasingly identified, as are effects in terms quality losses, economic costs and emissions costs (FAO's SOFA report 2019).

While FLAW reduction has huge benefits, the costs of action cannot be ignored when aiming for effective and efficient solutions. A comprehensive approach of cost of action versus cost of inaction may be helpful.

Efforts to collect and analyze data need to double down, not only for reporting purposes, but also for the identification of causes of FLAW and decision-making for action by all players in value chains. We encourage agencies in charge of these metrics and analyses to step up efforts in these areas, donors to enhance financial support, and call upon the private sector to report on a volunteer basis. The conference explored approaches to measurement in economic, nutrient, and quality-adjusted terms, and called for broader country coverage of data as well as reporting on progress towards 2030.

5. Research in science, technology and extension

We took note of progress made in terms of research, science and technology to address the FLAW problem. For example, the research initiatives by FAO, WRI, IFPRI (International Food Policy Research Institute), UNEP, the World Bank, the IADB, the InterAcademy Partnership, universities and others, highlight opportunities and challenges for research on food and nutrition security and sustainable food production, and propose priorities

for natural science, social science and food postharvest and food technology research on FLAW reduction.

Close cooperation among research communities and different stakeholders across the food system is called for to make progress on evidence-based FLAW reduction and action, including food market analysis, to understand the potential of solutions and innovations, and the feasibility of their adoption. The FLAW problem needs further clarification as to what it means to people and planet, and what it takes to move towards a more sustainable future. As waste is partly a behavioral issue, research on the behavioral aspects of FLAW needs more attention.

The causes of FLAW from a food system perspective need to be comprehensively investigated in order to avoid trade-offs across interventions if practiced within silos, and in order to point at their policy implications in the short and long term. The main knowledge gaps and the research agenda have been outlined in various recent publications, such as the InterAcademy Partnership report on "Opportunities for future research and innovations on food and nutrition security and agriculture" (2018).

We note the need for urgent action, especially in Sub-Saharan Africa, Central and Southern Asia and other developing regions affected by high incidence of food insecurity and food loss.

Pathways to effective alliances need to reflect a systemic approach to FLAW reduction, incorporating innovations in science and technology, and in monitoring food items transiting through the system. There is a role for extension services in dissemination, and for universities in building FLAW into their curricula. Information and communication technologies (ICT) and data science prove to be game changers in this respect. This conference is calling on the research community to communicate, coordinate and collaborate, and on governments, business and foundations to invest new resources to fund FLAW research.

Civil society actions: Civil society is taking action in areas related to FLAW. Different groups across the globe lead campaigns and disseminate information and good practices, educating consumers across all age groups and youth in particular, and advocating for more sustainable consumption patterns. Consumers are becoming aware of their environmental footprint when making choices on food purchases, portion sizes, packaging materials, and distance that foods travel. Other groups, such as Food Banks, have developed models to collect, repurpose and re-distribute food in urban settings.

We call for a broadening of efforts at the grassroots level from national or regional networks towards a global network. Efforts led by conscious

youth need support, including consumer and producer/farmer perspectives that care about the sustainability of planet and people.

Education, for instance through the global sharing of experiences of successful actions, can help countries identify solutions pertaining to issues of relevance tailored to specific circumstances. Toolkits in many languages for civil society organizations would be helpful. Dialogue on FLAW needs to be replicated more globally, reinforcing positive social norms, and engaging influencers and role models.

6. Religious communities' actions

Our conference was unique in terms of combining the science, policy, NGO and business communities with religious and ethics debates. As Pope Francis put it, "Fighting against the terrible scourge of hunger means also fighting waste. Waste reveals an indifference towards things and towards those who go without. Wastefulness is the crudest form of discarding. I think of the moment when Jesus, after the distribution of the loaves to the crowd, asks for the scraps to be gathered up, so that nothing would go to waste (cf. Jn 6:12). Gathering in order to redistribute; not production that leads to waste. To throw food away means to throw people away. It is scandalous today not to notice how precious food is as a good, and how so much good ends up so badly". (2019).

We call upon all religious communities not just to join actions to change behavior for waste reduction and investment initiatives for loss reduction, but to engage in leading such initiatives. Both loss and waste are moral issues causing harm beyond their economic and environmental tolls. Faith-based communities should initiate dialogues on acting together to support, advocate, and partner on reducing FLAW. We call on believers of all faiths to communicate through prayers and articulations by their leaders and communities for sustained change toward achieving SDG 12.3, halving FLAW by 2030.

7. Government actions

Governments at all levels need to set explicit, ambitious, and realistic FLAW reduction targets, measure the level and change of FLAW, and implement an effective and economically efficient FLAW reduction strategy. Some countries have invested in developing plans and actions to reduce FLAW. So far, however, they do not add up to sufficient global impact and joint action.

Investments in critical value-chain infrastructure need to be prioritized in low- and middle-income countries. Such investments would allow for

vertical coordination and modernization of value chains. The need for such investments is particularly acute when dietary patterns are changing, and demand for a more diverse and nutritious food basket, especially in urban areas, is rising. We take note of innovative solutions to finance such government plans. A case is the Sustainable Development Bond launched by the World Bank, and innovative financing solutions such as a Fund for investments for FLAW reduction might facilitate progress in this area.

Governments should also seek to redress incentive structures (including through price and regulatory measures like standards) such as those that encourage farmers and other supply chain actors, as well as retailers and consumers, to adopt practices that help reduce FLAW.

Furthermore, two issues need government consideration at macro scale: diversion from rule-based free trade can accelerate FLAW and needs attention; as FLAW accounts for a significant share of GHG emissions, the issue should feature on the action agenda of climate negotiations and Nationally Determined Commitments (NDCs).

8. Business case and corporate actions

A business case for addressing FLAW seems to exist, yet needs to be clearly demonstrated. Public support is initially required for implementation at scale and to reap societal benefits. A case in point is connecting to small farmers: As food companies aim to create value, business can lead the way in developing models that are more inclusive, also sourcing from small-scale producers. New product lines that are more sustainable will result from implementing business solutions that create shared value, and measure progress towards tangible targets. However, to convince customers, corporations need to assure transparency of actions and results in terms of FLAW targets.

Creativity is encouraged. For example, FLAW reduction can be a large domain for innovative start-ups targeted by the financial sector. Voluntary efforts being taken by businesses can be an effective mechanism if transparency of results is assured. Market-based approaches can help, but attention to impacts on low-income people and to the indirect effects on environments is necessary. Given simple metrics, setting targets and following up company by company, including input suppliers and employees of companies, is a practical approach.

Taking a shared value approach is promising when FLAW issues are included in corporate monitoring, auditing and reporting to shareholders. There are also roles for farmers, farmer organizations and small- and medium-sized enterprises to create awareness of the benefits of FLAW reduc-

tion and, where possible, seek collaborative responses (e.g. cooperative-organized cold chain development and other value chain improvements).

9. Joint actions, leadership and governance

This conference brought together representatives of all key groups of actors. Action areas for each of them have been outlined actor-by-actor in the previous points. Yet, to address the FLAW challenge effectively requires more collective action. We call for joint government, and private sector action at the global, regional, country levels, with engagement by religious communities, civil society and consumers. Such joint actions were identified at the conference and include, for instance:

1) Alliances of different actors require clearly defined strategies to reduce FLAW (e.g., among farmers, traders and the corporate sector, as well as among funders).
2) Government commitments to measure and report on FLAW metrics are essential for joint actions. For this SDG 12.3.1.a (for losses) and SDG 12.3.1.b (for waste) are the indicators that need to be collected.
3) Institutional innovations and incentive systems are required to bring together broad, stable and well-funded alliances for the reduction of FLAW.
4) Examples of joint actions need to be systematically assessed and evaluated in relation to their effectiveness. This can provide the bases for good storytelling.
5) Increased, aligned, and coordinated investments (and information on investment returns) will help to expand investments further.
6) Initiatives for complementary and joint action between civil society and businesses can be win-win if based on mutual respect and well-defined goals.
7) Joint action for FLAW must also address food safety, to ensure that foods are properly handled, stored, and prepared according to strict health and consumer protection standards. Moreover, supply chains should be carefully checked to prevent the use of forced labor and modern slavery.
8) Pathways toward a global action plan and key commitments to address existing knowledge and research gaps and investments for the realization of SDG 12.3 need to be promoted.
9) Our conference could be catalytic at best. Much more is needed. A focused food loss and waste summit conference should be considered, and the planned 2021 United Nations Food Systems Summit led by FAO with IFAD, WFP, and others, in addition to other global high-level gatherings, should include a strong focus on FLAW reduction. FLAW

reduction action for the achievement of SDG 12.3 needs a facilitating mechanism, adhered to by United Nations, governments, civil society and the private sector.

10) We aim for coordinated communication efforts to raise the profile of the FLAW issue in the media and mobilize civil society and the religious communities to embed FLAW reduction efforts as part of an inclusive and sustainable food system.

The Statement has been signed by:

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II: THE PROBLEM AND DESIGNING POLICIES TO ADDRESS FOOD LOSS AND WASTE

Moving Forward on Reducing Food Loss and Waste

Qu Dongyu[1]

Introduction: Three guiding posts to inform policy actions

International attention on the issue of food loss and waste is firmly reflected in the 2030 Agenda for Sustainable Development. Specifically, Target 12.3 of the Sustainable Development Goals (SDGs), which embody this agenda, calls for the halving by 2030 of per capita global food waste at the retail and consumer levels and the reduction of food losses along production and supply chains, including post-harvest losses. The increase in awareness started with a few publications that raised the profile of food loss and waste. Parfitt et al. (2010) was very influential as was an FAO report that estimated that one third of food produced was either lost or wasted (FAO, 2011). Concerning post-harvest losses, the World Bank (Zorya et al., 2011) highlighted the importance of PHL in cereals in Sub-Saharan Africa.

A decade later, many countries are taking action to reduce food loss and waste, but the challenges ahead remain significant and we need to step up efforts. Meeting SDG Target 12.3 could contribute to meeting other SDG targets, not least that of achieving Zero Hunger, in line with the integrated nature of the 2030 Agenda. This chapter provides a brief overview of challenges and options, highlighting that, although food loss and waste (FLAW) reduction is at the forefront of the policy debate, the evidence that can inform policymakers on the topic is extraordinarily sparse and heterogeneous in terms of methods and definitions. Being aware that FLAW is a problem is just the first step towards addressing it. A number of publications have started to provide insights that can help design interventions to reduce FLAW. Some are conceptual (Bellemare et al., 2017; Koester, 2017; Ellison et al., 2019) while others provide more of an overview (Affognon et al., 2015; Sheahan and Barrett, 2017; Xue et al., 2017; Aragie et al., 2018; Reynolds et al., 2019) or on methodology and measurement (Garrone et al., 2014; Delgado et al., 2020; FAO, 2019), as well as protocols being developed (FLAW protocol, 2016).

[1] Director General, Food and Agriculture Organization of the United Nations.

This chapter touches upon three dimensions that need to be considered. Firstly, we need to know – as accurately as possible – how much food is lost and wasted, as well as where and why. Secondly, we need to be clear about our underlying reasons or objectives for reducing food loss and waste – be they related to efficiency, food security or the environment. Thirdly, we need to understand how food loss and waste, as well as the measures to reduce it, affect the objectives being pursued. One of the main issues is that in the near future decisions will have to be made under very limited information. Clearly we need to continue working on monitoring and building an evidence base, but also provide guidance to policymakers based on the limited information we do have.

Concerning the first dimension, the surprising fact is how little we really know about how much food is lost or wasted, and where and why this happens. The broad estimate, prepared for FAO in 2011, suggested that around a third of the world's food was lost or wasted every year. This estimate is still widely cited due to a lack of information in this field, but it can only be considered as very rough. It is therefore in the process of being replaced by two indices, thanks to efforts by FAO and UN Environment to estimate more carefully and more precisely how much food is lost in production or in the supply chain before it reaches the retail level (through the Food Loss Index) or is subsequently wasted by consumers or retailers (through the Food Waste Index). Current estimates made by FAO for the Food Loss Index (FLI) tell us that globally, for the year 2016, around 14 percent of the world's food is lost from post-harvest before reaching the retail level. This global estimate is useful in conveying the magnitude of the problem. However, to intervene effectively we need to look beyond the global numbers and understand where in the food supply chain losses and waste are concentrated and the reasons why they occur. The FLI development is part of a broader process, in collaboration with many countries that supports such an effort.

Literature and the FLI show that losses and waste tend to be higher for some specific commodity groups, although they can occur at all stages of the food supply chain to different degrees. However, what is striking is the vast range in terms of percentages of food loss and waste for the same commodities and the same stages in the supply chain both within and across countries (FAO, 2019). This suggests that there is considerable potential to reduce food loss and waste where percentage losses are higher than in other places. However, it also shows that we cannot generalize about the occurrence of food loss and waste across food supply chains but must, on

the contrary, identify critical loss points in specific supply chains as a crucial step in taking appropriate countermeasures.

Regarding the second dimension, although the SDGs include the reduction of food loss and waste as a target in its own right, we need to be clear about why we are pursuing it – or what is the underlying objective. Individual actors, from primary producers right up to consumers, may have a private interest in reducing food loss or waste to increase their profits or income, their personal well-being or that of their families. However, this private incentive is not always strong since reducing food loss and waste may require investing money or time which, in the perception of these actors, could outweigh the benefits (Ellison et al., 2019). There may also be barriers that prevent private actors from making these investments, e.g. credit constraints or a lack of information about options for reducing food loss and waste. On the other hand, there may be a stronger public interest in reducing food loss and waste because it contributes to other public objectives, be they environmental or linked to food security and nutrition (Kummu et al., 2017; Neff et al., 2015; Shafiee-Jood and Cai, 2016; FAO, 2019; Global Panel, 2018; Springmann, 2018).

The potential public benefits call for public interventions in the form of investments or policies that create incentives for private actors to reduce food loss and waste or remove the barriers that prevent them from doing so. To understand the magnitude of the food loss phenomenon the value of these losses is upwards of 400 billion USD, and in terms of GHG emissions, the food lost is associated with around 1.5 gigatonnes of CO_2 equivalent. From a nutritional point of view, this is equivalent to more than 1,000 trillion milligrams of phosphorus and more than 350 trillion milligrams of magnesium.[2] Clearly the magnitude of impacts in these different policy-relevant dimensions is a call to action. However, linkages between food loss and waste, on the one hand, and food security and environmental impacts, on the other, are complex and need to be thoroughly understood. Positive outcomes from reducing food loss and waste are far from guaranteed, and the impacts will differ according to where food loss and waste is reduced (FAO, 2019; Cattaneo et al., 2020).

[2] These estimates are based on data used to produce FAO's newly developed Food Loss Index, extrapolating the impacts to include commodities that are not included specifically in the FLI commodity groups, but are represented by the groupings. These estimates are lower bounds because pre-harvest and harvest losses are not included in the FLI estimate.

The third dimension implies policymakers need to be clear about the objectives they choose to pursue. Focusing on one objective will indeed have implications for where food loss and waste reductions can be most effective. For instance, if the objective is to improve food security, reducing on-farm losses – particularly on small farms in low-income countries with high levels of food insecurity – is likely to have strong positive impacts. It may directly improve food security in the affected farm households and may also have positive effects in local areas, and even beyond, if more food becomes available. Reducing food loss and waste further along the food supply chain may improve food security for consumers, but farmers may actually be negatively affected if demand for their produce declines. On the other hand, while reducing consumer food waste in high-income countries with low levels of food insecurity may have some impact on vulnerable people locally through food collection and redistribution initiatives, the impact on the food insecure in distant low-income countries is likely to be very small (FAO, 2019; Rutten et al., 2015).

If the objectives for reducing food loss and waste are essentially environmental, interventions may be guided by the specific environmental objective being pursued. In the case of GHG emissions, since these accumulate throughout the supply chain, then cutting waste by consumers will have the biggest impact because food wasted at this stage represents a larger amount of embedded GHG emissions. In the case of land and water, the environmental footprint is tied mainly to the primary production phase. Therefore, reducing food loss and waste at any stage of the food supply chain can contribute to reducing overall land and water use at the global level. More guidance can be provided based on the environmental impact of value chains for specific commodities.

The need for better evidence to inform policymakers

Efforts to improve the evidence base are key. In 2019 the FAO prepared new food loss estimates to monitor progress in the context of the SDGs. The FLI monitors percentages of food removed from the supply chain over time, relative to a base period currently set at 2015, in order to track progress against SDG target 12.3. The Inter-Agency Expert Group on SDGs has approved the FLI and upgraded it to Tier II, meaning the indicator is conceptually clear and has an internationally established methodology, and that standards are available.

Although progress in monitoring food loss is being made, the limited data provided by countries remains an underlying constraint. Fabi et

al. (2020) state that in the short run, the only available option is making the best use of existing information. Data owners and researchers may use common repositories of international organizations such as the World Bank, the APHLIS, the WRI and the FAO, where information can be shared, harmonized to the extent possible, aggregated, and employed in estimation models to generate policy-relevant evidence, which is what FAO is currently doing with the FLI.

As for selecting commodities, given that estimating losses for many commodities across all countries is operationally challenging, the FLI focuses on the top ten commodities by economic value within five commodity groups for each country: 1. cereals and pulses; 2. fruits and vegetables; 3. roots, tubers and oil-bearing crops; 4. animal products; and 5. fish and fish products. Given cost-effectiveness concerns for data collection, the FLI helps improve the evidence base of losses by selecting only a few critical products and focusing on improving the data quality for those.

An important aspect of measurement is the one of units and whether they are suited to measure a specific objective, be it social, economic or environmental (FLAW protocol, 2016, Appendix D). The FLI is based on the economic value as reflected by farmgate prices of commodities, which may be highly relevant when devising interventions to reduce food loss as it accounts for the costs and benefits of loss reductions. However, food loss can be measured using a range of metrics depending on the objectives pursued. Caloric units may be more relevant in nutritional terms, in which case energy-dense foods will then have a greater weight in calculating food loss. However, if the policy focus is on environmental sustainability, for example with the objective of reducing greenhouse gas emissions, it can make sense to look at purely physical quantities such as tonnes lost and multiply them by an environmental impact factor. Next we examine what guidance can be provided by looking at percentage losses individually at product categories, and then using economic and environmental metrics.

Preliminary guidance and challenges based on the percentage losses by product category

In terms of food groups, roots, tubers and oil-bearing crops report the highest level of loss, followed by fruits and vegetables (Figure 1). It is not surprising that fruits and vegetables incur high levels of loss given their highly perishable nature. Results for roots, tubers and oil-bearing crops are mainly driven by cassava and potato losses, given the significant amount of data reported for these commodities. In fact, cassava is the most perishable of

roots and tubers and can deteriorate within two or three days after harvesting; potatoes, on the other hand, require careful handling and proper storage, especially in the warm and humid climates of many developing countries (FAO, 1998).

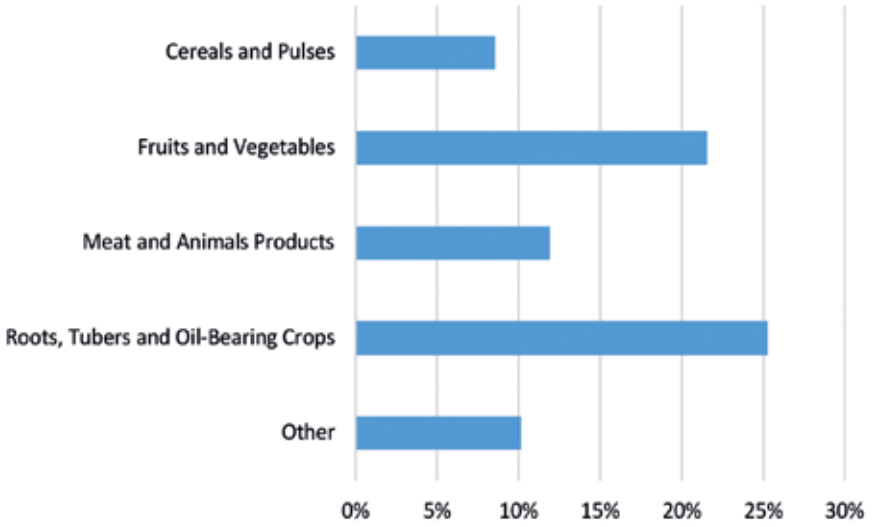

Figure 1. Food loss from post-harvest to distribution in 2016, percentages by commodity groups. Source: FAO (2019).

Measuring how much food is lost post-harvest is an important first step towards understanding what we are up against. However, understanding by how much it is viable to reduce such losses is still a challenge. As the evidence-base on postharvest loss reduction interventions is relatively sparse for most of the key staple food crops in SSA and South Asia, future studies should be conducted to increase the available data on key legumes, root and tuber crops, fruits and vegetables, which have among the higher loss levels. The limited evidence that does exist on postharvest loss reduction interventions may be extrapolated to other crops within each crop group (cereals, legumes, root and tuber, fruits and vegetables), however field level research studies should be conducted to confirm the validity of such an approach.

Within the limited evidence-base that does exist, the focus has been predominately on tangible technical interventions to reduce losses during storage in both durable (cereal, legume) and perishable (fruit, vegetable and root and tuber) crops, so future studies should take into account the

full value chain and the key actors (farmers, traders, wholesalers), with a particular focus on identifying critical loss points (Edwardson, 2018). Furthermore, in terms of the broader picture about addressing drivers of food loss, there is very little evidence available on the effect of any training, finance, policy or infrastructure interventions on postharvest loss reduction. Since these have not yet been studied systematically, future studies should incorporate these factors.

What can be gleaned from taking environmental and food security perspectives?

Despite this call to action to better understand the impact of interventions, the reality in the near future is that policymakers will have to make decisions based on limited information. One way to address the challenges of limited evidence is to target interventions in those value chains that are most relevant for the objectives being pursued. For example, policymakers interested in reducing the environmental impact of food loss and waste should first consider which environmental dimension to target (carbon, land or water) and which food products contribute most to that dimension's footprint when lost or wasted. Figure 2 provides estimates of the relative contribution of the main food groups to overall global food losses and waste in terms of quantities (first bar on the left), as well as to the associated carbon, land and blue-water footprints (second, third and fourth bars). The estimates include losses and waste from on-farm post-harvest up to the retail level, excluding consumption, and provide a general indication of which types of food products should be targeted if food loss and waste reduction is to contribute to environmental sustainability.

As illustrated by the first bar on the left of Figure 2, cereals and pulses account for the largest share of food losses and waste in quantity terms, followed by roots, tubers and oil-bearing crops, and then fruits and vegetables. The contribution of animal products to overall food losses and waste is limited, however their contribution to the land footprint of food loss and waste is not. Indeed, animal products account for over 60 percent of the total land footprint (last bar on the right). This percentage reflects the fact that livestock production requires substantial amounts of agricultural land to produce animal feed or for grazing (FAO, 2013a). Any interventions that aim to reduce the land footprint of food losses or waste should therefore focus on this product group.

If the aim of an intervention is to address water scarcity, then cereals and pulses should be targeted as a product group, followed by fruits and

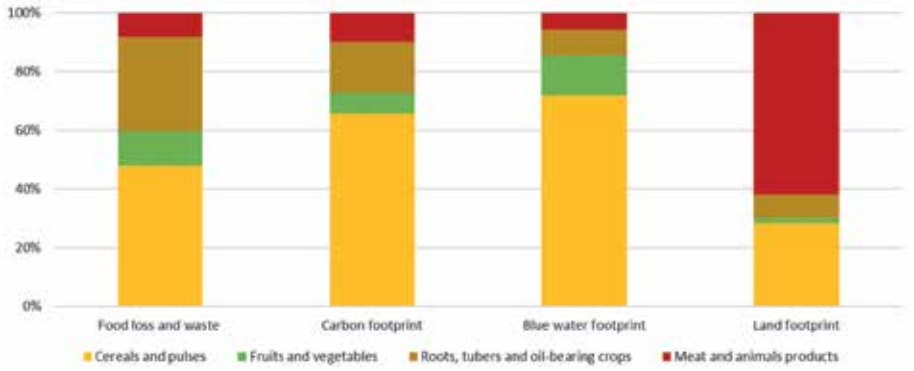

Figure 2. Relative contributions of the main food groups to overall food loss and waste and its carbon, blue water and land footprints. Source: FAO (2019) Note: Environmental footprints are calculated by multiplying the amount of food lost and wasted by its environmental impact factors. The carbon, blue-water and land impact factors were taken from FAO (2013), which provides environmental impact factors for different products, regions and supply chain stages. The stacked bars present the relative contribution of a food group to total food loss and waste and to each of the environmental footprints of food loss or waste. The estimations of food loss and waste differ from the ones presented in Figure 1 with respect to the inclusion of the retail level, the loss and waste reported is the share in quantity terms (not relative to economic value), and the use of loss and waste data only for which an impact factor was available. Thus, food products that do not belong to any of the groups included in the Figure (e.g. coffee beans) are excluded from the graph due to the lack of data for impact factors, despite contributing around 20 percent to food loss and waste. These data refer to 2015.

vegetables. Together, these two categories account for nearly 90 percent of the water footprint of total food loss and waste. This percentage reflects the fact that a significant share of irrigation water is used to produce these crops, especially wheat, rice and maize (Mekonnen & Hoekstra, 2011). The livestock sector contributes relatively little to the blue-water footprint associated with food loss and waste, possibly because the average blue-water footprint of animal products incorporates the footprint of livestock systems that do not use irrigated feed grains. Animal products from systems that use feed produced on irrigated fields may well have a larger water footprint than other food groups (FAO, 2013b).

Concerning GHG emissions, the largest share is linked to cereals and pulses because of the volume of losses and waste in these value chains. The relative contribution of animal products to total GHG emissions associated with food losses and waste is limited, due to the limited share of these products in total food losses and waste, but the carbon footprint per tonne

of animal products is the largest of all food groups, with the exception of cereals and pulses (FAO, 2019).

Taking a different perspective, a reduction in on-farm losses may have strong positive food security impacts. This holds particularly for smallholders in low-income countries where the availability of food to subsistence farmers improves. Farmers who market part of their output have larger volumes to sell and thus their incomes and food security may increase, provided the price drop resulting from the output boost does not offset this effect. On the other hand, a reduction in losses or waste by suppliers beyond the primary production stage boosts supplies and lowers prices further along the supply chain. However, farmers may see the demand for their products decrease, with negative implications for their incomes and thus food security. A reduction in the amount of food wasted by consumers will likely improve food availability and access for consumers, but the resulting reduction in consumer demand may leave farmers and other actors in the supply chain worse off. This highlights that food security and nutrition outcomes will likely be affected by the point of intervention in the value chain to reduce food loss and waste.

The above provides a general indication about what value chains one could target for interventions depending on the environmental or food security objectives. However, it should be noted that there is a lack of evidence regarding actual social, economic and environmental outcomes of postharvest loss reduction interventions, as technical efficacy of interventions has been the primary focus to date. Future studies should include measurements of these non-technical factors in their designs.

Another dimension that is often mentioned, but understudied, is the link between postharvest losses in the quantity and the quality of food crops and household food and nutrition security and income. More evidence is needed in this area on the efficacy of postharvest loss reduction interventions, particularly when combined with non-technical aspects such as training and handling practice change interventions. It is also important to improve understanding of the combined effect of financial, policy and infrastructural interventions and more participatory learning approaches on nutrition and food security.

Policy recommendations

The 2019 State of Food and Agriculture Report, focusing on FLAW, builds on the business case for private investments and efforts to reduce food loss and waste through private incentives. After doing so it expands the

rationale beyond the business case to one for public interventions, to reduce some of the barriers that prevent producers and consumers from reducing food loss and waste, e.g. generating and/or sharing information on how to reduce food loss and waste. Beyond that, public interventions should focus on providing public goods or reducing negative externalities (FAO, 2019).

In this context, technological solutions for post-harvest management, donor- and private sector-supported promotion is already occurring at different scales. However, for improved postharvest management and loss reduction, we need recognition that:

i. Greater awareness-raising of the ability to, and benefits of, reducing losses is required;
ii. Options need to be tailored to specific contexts – the technologies have strengths and weaknesses and due to the existence of significant differences between households, agro-ecologies and crops, one-size-fits-all solutions are unlikely;
iii. Technical solutions need to be simultaneously introduced or promoted alongside good postharvest management training to build understanding of why losses are occurring, and how the technologies can best be used;
iv. Implementation of policies that support quality-sensitive markets are needed to drive improved postharvest management and loss reduction.

At the same time, it should be recognized that broader policies (beyond technology) to promote overall rural development may allow producers along the supply chain to make investments that will also reduce food losses. In this respect, supportive national policies, infrastructure and access to finance are important, but there is currently an evidence gap regarding in which ways and how effectively these interventions can help.

Based on both private and public interventions to reduce food loss and waste, it is possible to provide some guiding principles for interventions. Clarity about the objective(s) being pursued is essential for identifying the most appropriate policies and entry points for reducing food loss and waste. This is particularly the case if financial resources are limited, and information is scarce, whereby policymakers may decide to focus on specific segments of a value chain depending on the underlying objective being pursued.

If the focus is on economic efficiency, an attractive option is to enable the business case for food loss and waste reduction, wherever it may present itself along the supply chain or geographically. However policymakers will have to take into account that food loss and waste reductions will have winners and losers. The benefits (or costs) are not always enjoyed (or borne)

by those implementing them (HLPE, 2014) For instance, as already noted, a reduction in food losses by processors may reduce the demand from processors for farmers' output, thus depressing the income of the latter.

When thinking in terms of public benefits of FLAW reductions, a focus on food security will tend to favour interventions early in the food supply chain, where positive food security impacts will be felt throughout the rest of the supply chain. To reach environmental objectives, food loss and waste reduction needs to take place downstream of the environmental impact. Finally, location matters when pursuing food security and nutrition or environmental objectives, the only exception being a fall in GHG emissions which has the same impact on climate change wherever it occurs.

Different countries will have different objectives to guide their choices. Low-income countries will likely want to focus on improving food security and nutrition, in addition to the sustainable management of land and water resources. This calls for a focus on reducing food loss and waste early in the supply chain, including at farm level, where impacts will be the strongest and losses tend to be the largest. High-income countries with low levels of food insecurity will likely place the emphasis on environmental objectives, in particular the reduction of GHG emissions. This will call for interventions later in the supply chain, in particular retail and consumption, where levels of loss or waste also tend to be the highest.

In situations where reducing food waste is identified as a priority, campaigns to raise awareness among consumers about how much food they waste, how it affects their household budget and what they can do about it, have been successful in a number of countries (FAO, 2019). Another avenue to reduce food waste is through support to food banks, which can help meet the needs of part of the food insecure population in a country while reducing food waste.

Finally, a critical issue is that of policy coherence and trade-offs between objectives, which requires that all options are weighed together for their impact to arrive at solutions that promote one objective without unintentionally harming another one. Some policies, for example those for improving food security and nutrition, may actually lead to increased levels of food loss and waste because they involve access to safe and nutritious diets with nutrient-rich foods that are often highly perishable. However, this should not be seen as a problem; the basic question is rather whether food loss and waste occurs because of an inefficient and distorted food system, and if it is possible to take measures that reduce food loss and waste without compromising food security and nutrition.

Policy coherence is important also because the amount of food loss and waste that can feasibly be reduced will depend on the costs and benefits relative to the status quo. Public policies affecting food prices can change incentives for consumers and producers to avoid loss and waste of food. If not well designed, agricultural policies or those with food security and nutrition objectives, e.g. food subsidies, may have unintended consequences by creating a disincentive to avoid food loss and waste. Therefore, reducing food loss and waste can also be furthered through the reform of policies that unintentionally lead to greater food loss and waste.

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IFAD's Experience Minimizing Food Loss in Developing Countries

Gilbert F. Houngbo[1]

Post-harvest food losses have been with us for as long as humans have cultivated land for agriculture. But today, in an era when we have the technology and knowledge to stem these losses – and with 821 million[2] people who do not have enough to eat each day and the earth's natural resources under pressure from climate change and population growth – it is unacceptable that so much food never makes it from the farm to the shop.

According to the most recent estimates, approximately 14 per cent of total food production is lost before it reaches the market,[3] but the magnitude of these food losses varies significantly across different regions and value chains. In sub-Saharan Africa, for example, an estimated 13.5[4] per cent of all grain crops, and up to 50 per cent of all fruit and vegetables[5] are lost after harvest. Reducing the loss of grains alone would save US$4 billion[6] a year and meet the annual caloric requirements of more than 48 million[7] people.

In poor rural communities of developing countries, however, very little food goes to waste, and all food that is lost is wasted; food that isn't eaten or sold is often used for animal feed, or turned into compost and ploughed back into the soil.

Food loss can occur for a variety of reasons, which differ widely across commodities and regions. For example, bad weather can curtail the harvest, or crops can rot in the field when there are insufficient workers to harvest and dry the crop on time. Market forces also play a role, with price fluctuations sometimes making it uneconomical for farmers to harvest and sell

[1] President, International Fund for Agricultural Development (IFAD).

[2] FAO The State of Food Security and Nutrition in the World (SOFI), 2019, p. 6.

[3] FAO The State of Food and Agriculture (SOFA), 2019, p. 8.

[4] http://siteresources.worldbank.org/INTARD/Resources/MissingFoods10_web.pdf p. 18.

[5] SOFA, 2019, Figure 6b (Page 26).

[6] http://siteresources.worldbank.org/INTARD/Resources/MissingFoods10_web.pdf p. xiii.

[7] Ibid.

what they have grown. At the storage level, produce can be contaminated by pests and molds, especially aflatoxins. During transport, fresh fruit and vegetables can spoil as a result of physical damage due to poor packing materials or inadequate refrigeration. Animal products can be contaminated through inefficient and unhygienic processing methods.

In sub-Saharan Africa, it is estimated that one-third of the population lives at least five hours away from the nearest market town of 5,000 people.[8] This means that produce has to be transported over long distances and often over bumpy, unpaved roads, before being sold. High levels of food loss occur when farmers are unable to get their produce to market because the roads are impassible or transportation costs are too high.

In order to combat food loss to meet our commitment to Sustainable Development Goal 12.3, and at the same time contribute to the first two Sustainable Development Goals to end extreme poverty and hunger, we need to pay more attention to the needs of the small-scale farmers in developing countries.

The world's small-scale farms produce half of all food calories on 30 per cent[9] of the world's agricultural land. In Africa and much of Asia, small-scale farms are the rule rather than the exception, providing essential employment and income for upwards of 60 per cent[10] of the rural population.

The International Fund for Agricultural Development (IFAD) has long recognized that reducing food losses can make a significant contribution to sustainable rural development by improving food security, nutrition, food safety, and income generation. As some of the interventions outlined below demonstrate, what appear to be small changes to the way food is stored and handled can greatly reduce the volume of food loss.

Between 2013 and 2016 IFAD invested US$433 million[11] to minimize food losses along food supply chains. These investments supported improvements in transport and storage facilities, the purchase of equipment for the processing and handling of food after harvest, and the training of farmers and others involved in the food value chain.

[8] https://pdfs.semanticscholar.org/f2cb/d3f72cb333c1cc6fd3eba6d5bc8bb8c89469.pdf p. 18.

[9] Samberg et al. 2016. Subnational distribution of average farm size and smallholder contributions to global food production. *Environmental Research Letters* Vol 11 (12). http://iopscience.iop.org/article/10.1088/1748-9326/11/12/124010/meta

[10] The State of Food and Agriculture (FAO), 2017, p. 68.

[11] The Food Loss Reduction Advantage (IFAD), 2019, p. 7.

Timor-Leste, in Southeast Asia, is one of the poorest countries in the world but with a fast-growing population. Around 40 per cent of the population is under 14 years old.[12] More than half of children under five suffer from chronic malnutrition.[13] The annual "hungry season", when food is hard to come by, lasts for 3.9 months and affects 95 per cent of rural households. A second hungry season of 3.6 months affects nearly one-third of the rural population.

The main crop in Timor-Leste is maize, accounting for more than one-third of food production. Traditionally, farmers hang the maize cobs on racks or in trees after harvest to complete drying, and then store the cobs in a loft above the kitchen fire, in a storage barn on stilts or suspended in a tree. As much as 15 per cent of the harvest stored this way – some 31,250 metric tonnes worth about $17.5 million – is lost annually to damage from rodents and weevils.

An IFAD-supported programme distributed 41,337 steel drums to 23,000 maize-growing households from 2011 to 2015. The drums were selected for their proven ability to reduce on-farm storage losses and for their suitability to the local context. The drums can be hermetically sealed, which kills off any potential pests and eliminates the need for further treatment (e.g. with pesticides) to prevent insect attack. This simple technology, with a life span of 25 years, is a very cost-effective and effective way to reduce grain losses, even for poor farmers.

Previous government programmes supplying free storage drums in Timor-Leste had underperformed, mainly because the drums were either mis-used or not used at all by beneficiaries. To encourage farmers to value the drums and use them effectively, the IFAD-supported project required beneficiaries to contribute $10, which the project then matched with an additional $40. As a result, there was a high rate of appropriate use among poor rural households, with 93 per cent used correctly for maize storage.

Among farmers who adopted the drums, maize storage losses dropped below 1 per cent from 15 per cent, resulting in each family having an additional 80 kilograms of staple food. The number of households experiencing a first hungry season fell to 33 per cent from 95 per cent; and to 6 per cent from 31 per cent for the second hungry season. The rates of childhood malnutrition also declined as a result.

[12] https://theodora.com/wfbcurrent/timorleste/timorleste_people.html
[13] The Food Loss Reduction Advantage (IFAD), 2019, p. 9.

In addition to protecting stored grains against pests, the drums reduced the risk of contamination by moisture-reliant pathogens; as a result of the intervention, the project area now has the lowest occurrence of mycotoxin in the country. For the farmers, the investment in the subsidized drums generated a 300 per cent return, rising to 400 per cent with the introduction of new maize varieties promoted by the programme's partner Seeds of Life.

One of the leading causes of food loss associated with inadequate storage facilities is lack of access to markets. It can be particularly problematic for valuable but highly perishable foods such as fish and dairy that need to be transported efficiently and safely, without the risk of spoilage or other losses. As a response, in Kenya and Mozambique, IFAD invested in two quite different food projects that reduced losses by making markets more accessible to small-scale producers.

Milk is big business in Kenya: its production, processing and distribution represent 4 per cent of the economy.[14] Yet, for all its scale, the Kenyan dairy industry remains a local business with 80 per cent of output coming from small-scale producers. The milk trade is a vital employer as well as a contributor to the cash economy, but it suffers from weak infrastructure. Farms are remote and roads to market are inadequate and poorly maintained. Milk processing equipment for cooling and pasteurizing is often absent, creating serious hygiene problems in the informal dairy trade. The lack of processing facilities results in deterioration, with loss of quality, volume and value for farmers and traders.

An IFAD study found that 2.7 million litres of milk worth more than half a million dollars were lost every year due to poor infrastructure in the Rift Valley and Western and South Nyanza regions. Further studies showed that poor roads and inadequate milk collection centres were the main factors behind milk marketing inefficiencies and high post-harvest losses.

Between 2005 and 2019, IFAD supported a US$40 million programme aimed at fostering market-driven development of Kenya's informal dairy industry. In addition to working with dairy groups to improve their capacity to market their milk and dairy products, and to enable access to equipment for pasteurization and cooling, the programme also worked with county governments to improve 2,000 kilometers of rural roads and install milk handling and cooling facilities in the programme areas. The

[14] The Food Loss Reduction Advantage (IFAD), 2019, p. 19.

investments helped reduce milk losses by 26 per cent in the project area, with an annual economic gain of about US$240,000.

Lack of infrastructure is also a significant cause of food loss in artisanal fisheries. In Mozambique, small-scale artisanal fishing generates about 9 per cent of the total marine catch and supports the livelihood of around 334,000 people. Most fishing communities are small, isolated and poor. Post-harvest losses affect fishing operations at all levels of the value chain: fresh fish deteriorates quickly due to limited availability of ice and insulated containers. Fish that is salted, dried or smoked is lost because of inadequate processing equipment, especially during the rainy season. More product is lost during transport as a result of poor local roads and lack of refrigerated trucks. And at the final point of sale, lack of ice or cold-storage facilities in local markets results in further losses.

To stem the losses and improve incomes, a recently completed IFAD-supported project trained 13,000 fishers in improved handling, processing and conservation of fresh and frozen fish. Sixteen fish markets were restored and 15 more were constructed in the programme area, each with sanitation facilities, water and electricity.

To link fishing communities to markets, the project funded the improvement of 525 kilometers of roads. A further 127 kilometers of electricity lines were constructed to connect the fish markets to the national grid, while eight markets were provided with solar panel systems for ice making and cold storage.

The resulting increase in access to ice and refrigerators has contributed to improving the quality of the fish and reducing losses, while better roads have reduced transportation costs and allowed better access to markets. As a result, the value of fish quadrupled in the project area.

Reducing food loss may seem like a relatively straightforward objective. But as the 2019 State of Food and Agriculture report notes, actual implementation is not simple[15] because food systems are a complex web connecting many different elements including nutrition, water management, marine resources, terrestrial ecosystems, food access, food prices, and even cultural heritage. As a result, an action taken in one area may have an unanticipated impact elsewhere in the food system.

For example, the adoption of cold storage and plastic packaging, while effective in reducing food loss, may lead to an increase in the total energy

[15] SOFA, 2019, page xii.

use and environmental footprint of food. Environmental trade-offs can be minimized by adapting climate-sensitive approaches and technologies, such as green cold storage options and reusable or compostable packaging.

In Rwanda, agriculture is the leading economic activity, employing more than 70 per cent of the country's workforce. Despite government investment and significant improvements in agricultural productivity, post-harvest losses are high. Recent changes in rainfall patterns during the harvesting season are leading to increased crop losses during drying and storage, as well as higher incidence of aflatoxin contamination.

IFAD is currently supporting an US$83 million climate-resilient Post-harvest and Agribusiness Support Project (PASP) to introduce pro-poor and climate-resilient approaches to post-harvest activities at a time when Rwanda is increasingly affected by climatic uncertainty. The project has co-financed more than 414 business plans to date, submitted by farmers' organizations and small and medium-sized enterprises for climate-smart post-harvest investments.

Smallholder households have gained access to improved technologies for climate-resilient drying, processing, value addition, packaging, storage, logistics and distribution, reducing their losses and improving their resilience to climate change. Further funding was provided through IFAD's The Adaptation for Smallholder Agriculture Programme (ASAP) to upgrade and climate-proof existing post-harvest facilities and support the design of more climate-proof post-harvest infrastructure. This includes the installation of ground and underground rainwater harvesting and storage systems, solar energy to provide light and power to warehouses, waste treatment systems, and machines designed for producing biodegradable bags.

In order to scale-up the impact of interventions and ensure a sustainable reduction of food loss worldwide, better data and policies are needed both at the national and global level. The collection of accurate data is key to ensuring that interventions are targeted and effective – and that they do not have any unintended negative side-effects. Reliable data is also important to help measure impact and progress towards SDG target 12.3 to halve per capital global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses by 2030.

There is also a need for policies and actions to develop rural infrastructure so farmers can get food safely and in good condition to market. Farmers have little incentive to invest in higher productivity or post-harvest storage and safer transport packaging if much of their produce is lost during shipment, or if the bulk of financial returns go to the trader and

not the farmer. Yet national strategies addressing food loss are a rarity, and often governments lack the expertise and resources to incorporate evidence-based information into agricultural strategies.

The United Nations' Rome-based agencies are addressing this challenge through a joint project between the Food and Agriculture Organization of the United Nations, World Food Programme, and IFAD. The project is designed to fill in the knowledge and policy gaps in three African countries – Burkina Faso, the Democratic Republic of Congo and Uganda – while also contributing to raising worldwide awareness of existing solutions to food loss.

In the first phase, the project carried out detailed analysis to identify critical loss points for crops along the value chain. The results of the food loss analysis have enabled each country to integrate food loss reduction into its agriculture and development policy frameworks, while at the global level the project established a Community of Practice to share knowledge on the subject. This is just one example of the steps we can take to fill policy and data gaps.

Financing is another critical issue. We need to look at how to increase access to rural finance to allow households to invest in food loss reduction – such as using hermetic storage drums or bags that prevent grain pest infestation during storage. And we also need to consider how to meet the financing needs of small and medium-sized rural businesses.

Funding is also required to make improvements. Only 10 per cent of rural communities have access to even the most basic formal financial services. Improving access to financing requires partnerships with the private sector and governments. IFAD recognizes this and together with partners, recently sponsored the ABC Fund which was launched with partners European Union, the Asia, Caribbean and Pacific group of states (ACP), the Government of Luxembourg and AGRA. This impact fund seeks to stimulate private-sector investments in small and medium-sized enterprises in rural areas.

We are also exploring new options, such as a dedicated private sector financing programme that will crowd-in private sector investments and leverage private sector know-how and innovation to deliver scaled-up impact for small-scale producers and rural communities.

Conclusion

We need food systems that are inclusive of all members of society, that are profitable for small-scale producers, that provide sufficient and nutri-

tious food for all, and that are sustainable and resilient. Reducing food losses along the value chain may not be a "quick win", but by stopping the loss of food that is already produced, it can contribute significantly to reshaping our food systems, and in the process contribute to meeting the Sustainable Development Goals, especially on zero hunger and no poverty.

Action and Policy Priorities for Food Loss and Waste Reduction – Germany

Hans-Joachim Fuchtel[1]

I. Introduction

In Germany, twelve million tons of food are thrown away every year.
This is a staggering amount we believe.
The Federal Government is therefore doing everything within its power to bring about change.
But the question is: Why does so much food end up in the bin?
There is not just one answer to that.
There is one thing we are most definitely lacking and that is simply an awareness of our food.
And, as I would like to stress here: also for those who produce our food. For our farmers.
We are therefore also soliciting your support for a new awareness of agriculture at this conference.

II. German policies against food losses and food waste

Our strategy against food waste in Germany is based on various elements.
We regard it as crucial to have all relevant actors on board.
We must indeed learn again to value our food as what it is for everybody: A basic means of life.
Our "Too good for the bin" initiative has therefore been promoting the appreciation for our food since 2012.
With a view to consumers:
Come on now, folks: It doesn't always have to be the unblemished carrot, the crooked and wrinkled one also tastes good.
Food waste arises everywhere along the food supply chain.
We have therefore launched a National Strategy for Food Waste Reduction this year.

[1] Member of the German Bundestag (Federal Parliament), Parliamentary State Secretary to the Federal Minister of Food and Agriculture.

It involves all relevant actors, ranging from farming via processing, trade, and the catering sector, right up to the consumers.
Sectoral dialogue forums have a special role to play in the implementation. Their task consists in agreeing on specific measures and defining targets.
We started with the "Dialogue forum on the prevention of food waste in away-from-home consumption", for 14 percent of food waste is generated in away-from-home consumption. This corresponds to 1.7 million tonnes.
We are then going to bundle up everything in the National Dialogue Forum where the industry, scientific community and civil society will network across the entire food supply chain.
We will use this as a framework to find very specific solutions serving practical needs.
We have, since 2016, on an annual basis been awarding our "Too good for the bin!" federal prize for commitment in combating food waste in order to reward the best ideas against food waste.
And by promoting research and development, we want to advance the digitalisation of the delivery system between trade and food banks, for instance.
The aim is to significantly increase delivery volumes.
At global level, we want to help close knowledge gaps and share best practices.
Germany is involved in promoting the FAO's Bilateral Trust Fund in order to provide important expertise for the prevention of post-harvest food losses in developing countries.
We need a database in order to measure the efficacy of our actions.
The food waste levels along the entire food supply chain in 2015 were determined as a baseline for continuous monitoring until 2030.
We are thus creating transparency and ensuring a public debate. Because we always need to exercise vigilance in fulfilling this task.

III. Conclusion

Ladies and Gentlemen, as Hermann Hesse, writer and Nobel Prize laureate for literature from my home region in Württemberg, once noted so aptly: "Only the ideas that we actually live are of any value".
I would like to express my warmest thanks to the organizers for this excellent forum. May the blessings of the Lord rest upon it.

Role of SMEs (the Hidden Middle) in the Reduction of Food Loss and Waste in SSA

Nuhu H. Hatibu[1]

Introduction

The 2019 Africa Agricultural Status Report provided a robust analysis of the role of Small and Medium-Sized Enterprises (SMEs) – which it dubbed the hidden middle – in the food systems of Africa (AGRA, 2019). Findings and conclusions of the report presented below shows that SMEs are in fact the *"key players in the reduction of FLAW along the value chain from farm gate to consumers"*:

i) 80% of food consumed in Africa reaches the final consumers through trade by private businesses; and
ii) About 96% of the trade in food is domestic with only 4% exported.

Therefore, as a group, SMEs are the largest investors in wholesale, logistics, processing and retailing of food in the continent. It is evident that SMEs play two types of roles with respect to enabling the reduction of FLAW along the value chains in SSA (Figure 1). The first role is in the upstream of the farmers, where SMEs supply technologies and services that are critical to the reduction of food loss. In this role, SMEs are investing and running businesses that manufacture, import, distribute, hire out, operate and maintain equipment and other facilities that farmers use to harvest, handle and primary process their harvest. The second role is in the downstream of the farmers, where SMEs invest and operate facilities and services such as warehousing, cold storage, transportation and value-adding processing.

In its recommendations, the AASR called for a greater recognition of the proliferation of private SMEs in food systems and more direct *attention and investment to this sector.* This was similar to the call made by FAO and GAIN in 2018, on *leveraging SMEs to improve food and nutrition security.* The publication concluded that: *"SMEs play a fundamental role in getting healthy food to the consumers … if we are to achieve SDG Goal 2 and the other SDGs, we should have SMEs at the table"* (FAO & GAIN, 2018).

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Figure 1. SMEs positioning along the value chain in relation to reduction of FLAW (AGRA, 2018).

The fact that SMEs handle 80% of the food between production and consumption makes it even more compelling to support them because often in SSA, food safety may be a bigger problem emanating from FLAW. This is because spoiled food is not "thrown away", but rather most of it usually finds its way to the plates of the poor, leading to poisoning and other food safety risks. For example, mycotoxins in the forms of aflatoxins and fumonisins are endangering the health and lives of millions of people who consume, directly or indirectly, maize and other susceptible foods as staples (Mutiga, *et al.* 2015). Furthermore, residues of highly poisonous pesticides contaminate food presented as "unspoiled" (APHLI, 2014). The World Health Organization estimates that the burden from food safety-related diseases and poor health are at a par with HIV/AIDS, TB, or malaria (WHO, 2015). The World Bank has also provided data to show that impact of unsafe food costs low- and middle-income economies about US$ 110 billion in lost productivity and medical expenses each year – *all due to poor handling of food from farm to fork* (WB, 2018). Equally important, the loss of food trade opportunities is in the tens of billions of dollars (WB, 2015).

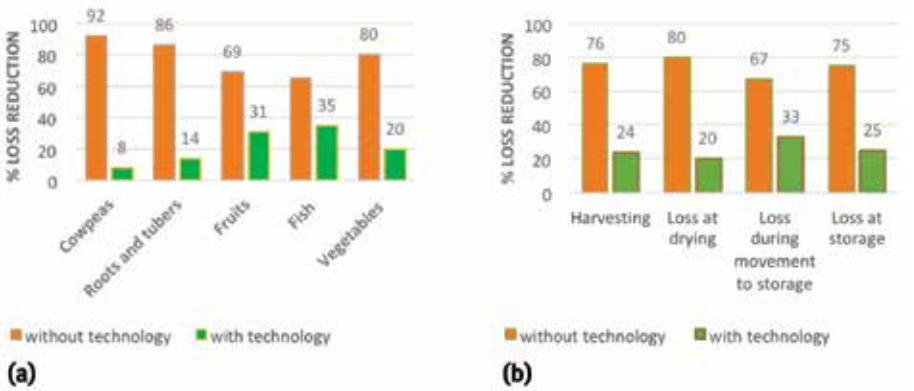

Figure 2(a). Food losses in the hands of SMEs between farm-gate to retailers – without and with technologies for loss reduction (Affognon *et al.*, 2015).
Figure 2(b). Food (*maize*) losses in the hands of farmers at farm level – without and with technologies for loss reduction (AGRA, 2018).

SMEs are critical in enabling smallholder farmers to reduce food loss

The Alliance for Green Revolution in Africa (AGRA) has been the lead-implementing partner in Tanzania for the maize component of the YieldWise Food Loss Reduction Initiative supported by the Rockefeller Foundation since 2016.[2] The initiative focuses on fruits, vegetables, and staple crops in Kenya, Nigeria, and Tanzania. One key lesson from the work in Tanzania is the significant role that SMEs play in enabling smallholder farmers to access appropriate technologies through manufacturing, distribution, operation & maintenance, and hire services. Another profound lesson is that SMEs are also critical in training and offering extension services to farmers on the technologies and associated practices for the reduction of food loss at harvesting, primary handling and storage (Mbaabu & Alela, 2019). Supplier-led demand creation is more effective for adoption and sustainability because it builds stronger linkages between the demand for technology and the business required for an adequate response to such demand.

Therefore, as illustrated in Figure 2, technologically empowered SMEs would contribute directly and indirectly to a reduction of between 84 and 30 percentage points in FLAW in SSA, through the adoption of advanced technologies and their proper use.

[2] https://www.rockefellerfoundation.org/our-work/initiatives/yieldwise

SMEs should be prioritized in key policies on food and agriculture

While SMEs must continue to thrive as private enterprises, policies for the general economy and for different sectors should recognize the role they play in the reduction of food loss and waste along the agri-food value chains. Lessons from the growth of SMEs in China provide some evidence of the kind of policies and strategies that enabled the tremendous growth of SMEs and enhance their role in food systems (Liu, X., 2008). These included setting-up of government departments with their core business dedicated to SMEs development: for example, establishment of local SMEs departments in every provincial government and the China Coordination Center for Cooperation of SMEs with foreign countries. This enabled the development, enactment and effective implementation of policies, strategies and programs that drive SMEs growth.

The national policy framework for support and development of SMEs in agro-processing in the Republic of South Africa (DAFF, 2016) is another example of policies specifically focused on SMEs dealing with food. The policy framework guides the deployment of public sector investment with respect to development of SMEs in relation to access to finance, modern technologies and infrastructure.

However, while recommending specific policies for SMEs, it is imperative that there is close coordination of such policies with other sectoral policies such as those for agriculture, trade, industry, energy, infrastructure, and finance (fiscal instruments, taxes and interest rates on credit facilities).

Public sector investment should be aligned with the needs of SMEs

Public investment in transport infrastructure, energy and modern wholesale markets have a significant effect on enhancing the investment and capacity of SMEs to reduce food loss. Energy is central to most operations in the value chain, thus its availability drives investment by SMEs in better systems for handling, processing and storing food. Therefore, public investment in generation and distribution of affordable and reliable energy is crucial. To this end, given the high cost of ensuring availability of grid power connections at all points along the value chain in SSA, it is important to pursue dispersed energy sources such as solar.

Therefore, public investment in primary industry to support the solar power sector would have the tremendously positive effect of providing affordable energy required in the reduction on FLAW by the SMEs. This is because, as elaborated by the International Renewable Energy Agency (2016):

i) Where the current source of power is grid-electricity, solar power would help overcome erratic, low-quality grid supply and, more importantly, the need for cash expenditure in power bills.
ii) Where fuel-based engines are used, solar-based solutions eliminate recurrent expenditure on fuels as well as problems caused by fluctuations in fuel prices.
iii) For areas currently stuck with no reliable power source, because of its "plug-and-play" nature solar power can be installed within a very short time to transform most of the operations along the value chain.

Another public investment aspect that is critical is ethical and functional institutions for standards and quality assurance – to provide an enabling environment for private sector investments. This is because transparent control, testing and inspections along food value chains drive standards across all players and create a momentum towards high standards. Equally important will be the deployment of digital technology to enable SMEs to measure and establish metrics and economic loss associated with food loss, so as to drive investment in reducing such loss. Furthermore, digital technologies have the capacity of empowering every consumer to undertake rapid assessment of food quality and contamination.

SMEs should be enabled to accelerate adoption of modern technologies

The focus should be to support SMEs to undertake technological *leapfrog* and adopt cutting-edge technologies and practices in prevention of FLAW (Davison, R. *et al.*, 2000). Because of the leapfrogging already registered for ICTs, computerized automation for high level of quality control of food handling, storage and processing, is a critical entry point. The main investments required to achieve leapfrogging will include, but are not limited to:

a) Adaptation of R&D to enable local manufacturing, efficient supply chain and after-sales services.
b) Enhanced access to expanded financial services, with emphasis on a lease/rent-to-own financing model, with the equipment serving as collateral. Smart subsidies can also be used to de-risk investment in new technology.
c) Promotion and demonstration of modern technologies through strong, supportive extension services and viable supply and after-sales-services.
d) Building technical skills and capacity of technicians in installation, operation, repair and maintenance of systems and equipment.

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Food Loss and Waste: Causes, Impacts and Proposals in Europe

Ludovica Principato, Daniele Fattibene, Marta Antonelli

The food loss and waste paradox

According to the most recent estimates, the world's population will have grown to approximately ten billion by 2050, which means that, if present trends persist, world food production will need to increase from current levels, putting pressure on the already limited natural resources. Approximately one third of global food production is currently lost or wasted along the food supply chain, which is paradoxical given that theoretically this wasted food could feed the 821 million people suffering from hunger four times over (BCFN, 2012, 2013; FAO, 2013). Along with the competition for natural resources between humans, animals and cars, as well as the co-existence of hunger and over-consumption of food, food loss and waste represent one of the food paradoxes identified by the Barilla Foundation since 2012 (BCFN, 2013).

Among the more perishable foods we waste the most, FAO estimates that around 45% of fruit and vegetables, 35% of fish, 20% of meat and dairy products are lost along the entire supply chain (Gustavvson et al., 2011).

If we look at the causes, food loss – i.e. the decrease in edible quantities of food in the early stages of the supply chain, from field to industrial processing – is more common in developing countries for economic/structural reasons. In fact, in these countries there is often a lack, or inefficiency, of infrastructure and storage facilities allowing the food produced to be managed, preserved and transported to the processing plants or to the points of sale. On the other hand, food waste – i.e. waste that happens at distribution and consumer level – is typical of western countries and occurs mainly for behavioral reasons. In the EU, for example, 70% of food waste occurs in the home and in the food service and retail sectors, with the production and processing sectors contributing the remaining 30% (FUSIONS, 2016).

As individuals, we often behave inappropriately or in ways that result in us throwing away food. Up to 30% of the food we buy is estimated to end up in the garbage can. At distribution level, waste mainly occurs due to incorrect management of the cold chain, stock rotation problems, or the

high aesthetic standards applied to products (Partfitt et al., BCFN, 2012).

Individuals waste food for a series of complex and multifaceted reasons framed by the "household food waste journey model", which highlights the incorrect behaviors and factors that drive wasteful behavior during the food management process, from planning the shopping to disposing of waste, considering psychosocial, situational, demographic and socio-economic variables (Principato, 2018). Food waste reduction is an integral part of a sustainable and healthy diet and is currently addressed through specific interventions, such as the EU-funded Su-Eatable Life project aimed at engaging students and employees in university and company canteens (Antonelli et al., 2019).

The impacts of waste are devastating. The economic impact alone amounts to $2.6 trillion a year globally (FAO, 2014). Given the magnitude of the phenomenon, over the past few years both institutions and the public-private sector have been moving forward with commitment, carrying out policies and initiatives to tackle waste. In the next paragraph we will discuss some of the projects implemented in Europe (EIU, BCFN, 2018).

European action against food waste: a supranational and urban perspective

An overview of EU policies

The unfair distribution of food in the supply chain does not only affect countries in the Global South. In 2018, EUROSTAT calculated that more than 36 million people cannot afford a good quality meal (including meat, chicken, fish or vegetarian equivalent) every two days in the EU (EUROSTAT). This is one of the reasons why, over the last decade, EU institutions have been working actively to promote a more sustainable vision of the food supply chain, in line with the targets set in the United Nations' 2030 Agenda and the Sustainable Development Goals (SDGs). In particular, a series of initiatives to fight food loss and waste have been promoted, with the aim of identifying the root causes behind it, and addressing the regulatory, economic and cultural obstacles that contribute to generating it. The Food Sustainability Index reveals interesting data on food loss and waste in the EU. On the one hand, it shows that every EU citizen generates around 60 kg of food waste per year on average, with the highest level recorded in Belgium (87 kg/per capita) and the lowest in Cyprus (36 kg/per capita). On the other hand, the Index highlights that, on average, 3% of to-

tal food production is lost, with the lowest levels recorded in Finland (less than 1%) and the highest ones in Slovenia (11%). Overall, the EU-funded FUSIONS project estimated that over 20% of the food produced in the EU was wasted (88 million tons per year), with an economic cost of 143 billion euros, accounting for 6% of total EU greenhouse gas (GHG) emissions. In this context the sectors contributing the most to food loss and waste generation are households (53%) followed by processing (19%), the retail sector (17%) and finally production (11%) (Stenmark et al., 2016).

At regulatory level, since Resolution 2175/2011 was adopted by the European Parliament in 2012, many institutional players (i.e. the European Commission, the European Economic and Social Committee, the Court of Auditors) have worked to set up a clear legislative framework to tackle food loss and waste (Ferrando and Mansuy, 2018). The process has been long and complicated as the topic touches upon several policies, ranging from waste management to food safety and information, research and innovation, environment, agriculture, education and social policy (European Parliament, 2017). Moreover, it involves a plethora of actors, including producers, processors, retailers and consumers. Against this backdrop, the first aim of the EU's action was to reduce the current regulatory gaps, to agree on a waste hierarchy (European Union 2018), to try to clarify date marking,[1] to provide guidelines for food donations and finally to identify targets for food waste reduction.

This work was part of a broader effort to approve a Circular Economy Package that eventually became Law in 2018 (European Union, 2018). The new legislation introduced new obligations for Member States, with the aim of reducing food waste generation at each stage in the food supply chain (i.e. primary production, processing/manufacturing, retail/other food distribution, restaurants and food services, households). In this context, the so-called Platform on Food Losses and Food Waste, established in 2016, brought together several actors from different backgrounds but also created the conditions for all members to define measures to redistribute surplus food, agree on a common definition of food losses and waste and share best practices. Such an approach allowed the Commission to achieve at least three main goals in the fight against food waste. First, it proposed a

[1] Citizens tend not to know the difference between "use by" and "best before" date. "Use by" date indicates the date until which food can be eaten, hence it is an indicator of safety. "Best before" date refers instead to the quality of food, as it shows that food can still be eaten, though it may lose flavour and texture.

common methodology for measurement (European Commission, 2019), second, it established precise guidelines to facilitate food donation (European Commission, 2017) and third, it issued guidelines for the feed use of food no longer intended for human consumption (European Commission, 2018). Finally, in 2019 the Platform launched a series of recommendations for the future, targeting all actors operating at various stages of the food supply chain and suggesting some areas of implementation by 2030 (EU Platform on Food Losses and Waste). The establishment of a common methodology will be a crucial step, as it will allow Member States to provide the first new data on food waste levels by mid-2022. In this sense, as stated in the new Directive 2018/851 on waste, this data will make it possible to publish a first EU-wide report on food loss and waste across EU members and may become a driver to introduce legally binding targets to halve food loss and waste from farm to fork by 2030, in line with SDG 12 (European Union, 2018).

The role of cities in tackling food waste

In recent years, EU cities have come to the fore as new crucial actors in the promotion of more circular food supply chains. Several mayors have put the fight against food waste at the top of their agenda. Figure 3 provides a map of some of the most relevant initiatives taken by a selection of 14 cities spread across 10 EU countries in the field of food loss and waste reduction.

The city of Milan is working on this at local level, for instance by introducing fiscal incentives (tax deductions) for food businesses (supermarkets, restaurants, canteens, producers etc.) that donate their food to charities, and internationally, for instance through the Milan Urban Food Policy Pact (MUFPP), as well as other groupings such as EUROCITIES and C40. In Belgium, Ghent in 2017 launched an innovative multi-stakeholder platform called "Foodsavers" with the aim of collecting surpluses from supermarkets and producers and donating them to charities. After the first 10 months of operation, 300 tons of food (with fruits and vegetables accounting for more than three thirds) were collected, involving 24 retailers, one wholesale market, two retail distribution centers, one organic farm and one company supplying food products. In addition, "Foodsavers" brought together 58 local charity organizations and social restaurants in distribution activities to reach almost 19,000 citizens in need. This led to an overall reduction in CO_2 of 762 tons as well as providing jobs for 19 long-term unemployed people (FAO and MUFPP, 2018). Finally, Riga has turned the Getlini waste landfill into a more innovative and environmen-

tally-friendly waste management site. The plant has become one of the biggest producers of green energy in Latvia (31 to 33 GWh annually), with the heat produced as a result of energy generation (20 GWh in 2015) used to heat greenhouses and provide up to 400 tons of off-season organically-produced tomatoes and cucumbers to the citizens of Riga, distributed through the primary supermarket chains (FAO and MUFPP, 2018). The economic and social impacts of this project have been huge, as the landfill has turned into of the biggest source of jobs in the suburbs, with almost 17% of employees coming from the neighboring district.

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European Approach for Reducing Consumer Food Waste; Putting Insights in Practice

Toine Timmermans,[1] Stephanie Wunder,[2] Erica van Herpen[3]

1. Enacting policy to drive food waste reduction

With an estimated contribution of 53%, the consumer is the primary contributor to food waste across the food chain in higher income countries (Stenmarck et al. 2016). Considering that a large amount of this waste could be avoided, the urgent need to change consumer behaviour is evident. Reducing consumer food waste and policy interventions to support this effort is therefore a key area of the EU project REFRESH, within which this report was developed. Reducing food loss and waste can help meet the UN Sustainable Development Goals (SDGs) by 2030, contribute to the Paris Agreement on climate change, and sustainably feed the planet by 2050. A Global Action Agenda was composed by a group of global experts in 2019 to help reduce food loss and waste and achieve SDG 12.3. This action agenda included 10 "scaling interventions" designed to take the approach and to-do list to scale (Flanagan, 2019). A follow-up report explores these 10 "scaling interventions", one being to shift social norms (Hanson, 2019). Leveraging the latest findings of behavioral science, the report engages grassroots campaigns, social media, religious communities, and others to make "wasting food" as unacceptable as littering now is in many countries.

2. Influencing factors of consumer behaviour

The factors that cause consumers to waste food are complex. Often food waste is a result of conflicting goals, such as convenience, taste, and saving money. Consumer food waste behaviour is determined by the following:

– Consumers' motivation (including attitude, problem awareness, and social norms around wasting food),

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– Consumers' opportunity (including time availability, access to technologies, and having the quality and quantity of food), and
– Consumers' ability (skills and knowledge) to control or change food waste-related behaviour.

Socio-demographic aspects such as age, gender, income and household size are also correlated with food waste as they influence motivation, ability and/or opportunity, but do not play a causal role. A visualisation of the theoretical framework is shown in Figure 1.

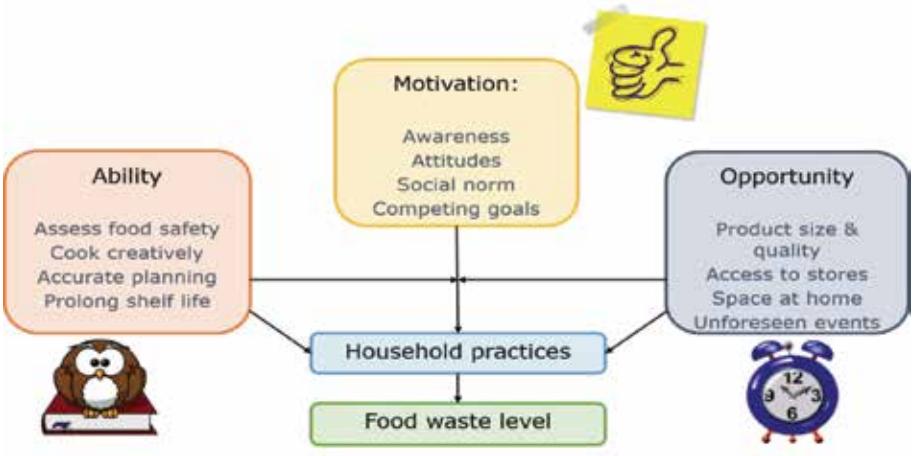

Figure 1. Visualisation of a theoretical framework of Causes & Determinants of Consumers Food Waste (modified by van Geffen, 2016).

REFRESH results of a survey in four countries with 3354 households shows that the awareness of the consequences of wasting food was not correlated with food waste levels, meaning that it did not show a significant influence (van Geffen et al. 2017). Social norms though have a clear influence, i.e. the more strongly consumers believe that others such as family members and friends waste food, the more food they waste themselves. Also, "busy lifestyles" and the prevalence of unforeseen events strongly influences food waste levels: Consumers who more often encounter unforeseen changes in their schedule tend to waste more food. It also shows that households with less food waste tend to exhibit five household food management practices: planning of food shopping and use, less impulse buying, maintaining overview of the food in stock, precisely determining

the amounts of food when cooking, and using leftovers. Injunctive norms refer to what others think you should do (i.e., whether others disapprove of you throwing out food). These types of norms have little or no effect on the amount of household food waste (Stefan, van Herpen et al. 2013). In focus group discussions about household food waste, the topic of social norms did not emerge explicitly (van Geffen et al. in press), which is likely because people tend to underestimate the effects of social norms on their own behaviour. In a cross-country survey on household food waste, descriptive social norms (i.e., whether you think that others waste food) had the strongest influence on the amount of food waste (van Geffen et al. 2017).

3. Policy instruments to influence consumer food waste

Policy instruments that exist to influence consumer food waste can be clustered into five categories:

- Information and awareness raising campaigns
- Regulation
- Economic instruments
- Nudging/change of consumer's choice architecture and
- Voluntary Agreements.

These instruments are often used in combination. Within the EU, the most often used instrument so far is public campaigns that have been designed to provide information that increases awareness on the negative impacts of food waste. However, there are only very few studies that have evaluated the extent to which these activities actually reduced or prevented food waste. Meta-analysis of pro-environmental behaviour experiments though have shown that intervention strategies that only provide information are the least successful (Osbaldiston and Schott 2012). Therefore, the common assumption that providing information is sufficient to induce behavioural change is not supported by the evidence. Policy makers should consider interventions based on regulation, economic instruments and nudging approaches. Where necessary, these approaches should be supported by carefully designed campaigns drawing on the latest insights from research.

3.1. Social norm campaigns

Research suggests that it could be helpful to design, implement and test campaigns that aim to influence social norms. Social norm campaigns exploit the tendency of individuals to conform to what they perceive those

around them think or do. Therefore, there is an opportunity to shape behaviour by giving people information about the behaviour or attitudes of others in the population, carefully selected to maximise adoption of positive behaviours. When (re)designing campaigns, policy makers should also consider using positive rather than negative messages, as research has shown messages that blame consumers for waste tend to have backfiring effects.

3.2. Education and provision of skills

The provision of practical skills aimed at consumers should be stronger in the focus of policy interventions. These need to build on an analysis of national particularities (e.g. which food items are wasted most and why) and key target groups (e.g. young people), and be tailored to existing knowledge and skills to influence the most relevant household food management practices. Education interventions including skill development can be set out via regulation, be it for schools, university curricula or job training (e.g. curricula for cook's education).

3.3. Feedback, prompts and personal commitments

Interventions that are not yet used very often, but can drive changes in consumer behaviour and should be tested are feedback, prompts and personal commitments.

1. Feedback refers to providing information about the frequency and/or consequences of a target behaviour, in this case the amount of food wasted.
2. Prompts are verbal or written messages that remind people of a desired behaviour, e.g. a sign at a buffet in a canteen "Come back as often as you want" or on-pack information: "Store me in the fridge".
3. Commitment is giving a pledge to change behaviour, asking people to agree to perform a target behaviour. Signing pledges or promise cards increases the likelihood of a person performing the behaviour to which they have committed and can be linked back to people's desire to behave, and appear to behave, consistently.

3.4. Regulation

There are relatively few ways to directly impact consumer food waste levels through regulation. Examples include regulation on date marking, requirements for packaging, or prohibition for certain practices. Also, education activities can be required through regulation, as e.g. done through both the Italian food waste law (Law 166/2016) and the French food waste

law (Law 2016-138). There are also other areas for regulation that do not directly target consumers but can indirectly reduce consumer food waste and/or which depend on changed consumer behaviour. These include:

- Relaxing marketing standards: marketing standards about size, colour, shape etc. of fruits and vegetables are often highlighted as a source of food waste for fresh produce. Evidence on the amounts of waste and savings potential associated with marketing standards is though mostly anecdotal.
- Increasing availability of new products from surplus food: One barrier to consumption of products made from surplus food and secondary resources is low supply due to the administrative burden of bringing novel food products to market
- Prohibition for supermarkets to waste edible food: The obligation for supermarkets in France with a surface area of over 400m² to establish contracts with charitable organisations to which they must donate their food surplus has received extensive media coverage.
- Requirements within public procurement regulation: The set-up of (green) public procurement rules for food provision in e.g. hospitals, school, and public canteens, can be influenced by public policy. Standards can be set e.g. related to the size portions, staff training or availability of dishes during daytime – all having an impact on food waste and providing consumers with the opportunity to reduce food waste.
- Regulation on waste collection and recycling: Waste regulation, requirements for separate waste collection, potentially combined with fees ("pay as you throw") and recycling of (organic waste) can have an influence on how much consumers waste.

3.5. Economic instruments

Only few public approaches are known in which fees and taxes are used to reduce food waste (e.g. incentives for donating food in Italy, penalties for supermarkets wasting food in France) and research about their impact is lacking. The price of food though and its share in household income already plays a role for food waste behaviour in general. Low prices for food in relation to income are seen as a reason for overconsumption and food waste. At the same time, extensive research has illustrated that if the real cost of natural resource use and the costs of food waste for the society was reflected in prices (i.e. internalizing external costs), food prices would need to grow (Willet et al. 2019). This would in turn provide economic incentives for food waste prevention.

3.6. Nudging

The modification of choice architecture – also called "nudging" – in selecting, processing and disposing (food) waste can be used as a strategy to reduce food waste. Nudging influences behaviour through automatic cognitive processes ("mental shortcuts") in favour of the desired outcome, i.e. they are "gently pushing" consumers in the favoured direction without forcing them. Nudges are a response to the so-called "intention-behaviour gap". Within the domain of consumer food waste the application of nudges has just started. Nudges such as changes to plate type and size as well as portion size and availability of trays have led to reduced food waste. Learnings from healthy food nudges can be used for decisions about placing certain food products in more visible and salient places. Nudging can be particularly powerful to reduce out-of-home food waste and is therefore relevant for canteens, caterers, restaurants etc. As public policy makers also shape the food procurement of hospitals, schools, prisons etc. nudging is an important element to be considered.

3.7. Strategies and Voluntary Agreements

In the area of food waste, collaboration across the supply chain can play a big role. The starting point is that interactions across the food supply chain are generally based on contracts, not on cooperation, and food waste prevention is rarely considered in such contracts. Addressing this requires a different approach, and voluntary cooperation may be one option for doing so. Voluntary Agreements are self-determined commitments or pacts with qualitative and quantitative objectives, developed by private entities and/or other stakeholders in consultation with their signatories. They are used as alternative courses of action to traditional legislation, can be piloted by government officials, businesses or other actors, and can be used in addition to, or independently from existing legislation (Burgos et al. 2019).

4. Evaluation of interventions

Though there have been many interventions, there are only very few studies that have evaluated to what extent these activities actually reduced or prevented food waste. This lack of evidence about how effective different interventions are at preventing consumer food waste makes it difficult for policy makers to make evidence-based decisions. Also, the few examples follow different assessment methodologies, so their results are not comparable. Most importantly, monitoring and evaluation needs to be considered early in the process: i.e. developed at the same time as the

planning for the intervention themselves. All too often, evaluation is only considered towards the end of the implementation phase, which is usually too late for effective evaluation. Within REFRESH, a detailed guidance document to evaluate household food waste interventions has been published (Quested 2019).

5. Integrated policies to reduce consumer food waste

Reducing food waste is an important international objective and for that reason also a central part of the global sustainable development agenda (SDG 12.3). However, the generation of food waste is not the only problem in the current global food system, nor is it the only problem that is related to food and consumers. Food systems are closely linked with health impacts. Consumer demand is also connected with ecosystem health and the agricultural production system: According to UNEP global food systems are estimated to be responsible for a third of degraded soils, a quarter of greenhouse gas emissions and 60% of terrestrial biodiversity loss. Many argue that the magnitude of the food waste problem is to a large degree a symptom of a dysfunctional food system. Policies against food waste therefore also need to look for synergies to achieve a more general shift towards a more sustainable and resilient food system.

6. Dutch case study, Social Norm campaign as pillar in a systemic approach at national scale

The charity SamenTegenVoedselverspilling (Food Waste Free United) is the national private-public initiative in the Netherlands to deliver target SDG 12.3, with the long-term ambition to lead the way towards a responsible and circular food consumption and production system. The design and set-up has been supported by the REFRESH project. SamenTegenVoedselverspilling focuses on achieving impact, with the target of reducing annually 1 million tons of food waste in the Netherlands in 2030. The approach is build on 4 pillars: (1) transparency, monitoring & impact, (2) business innovation across the food sector, (3) consumer activation and behavior change and (4) changing the rules and removing (legal) barriers. A diversity of stakeholders participate in the ecosystem and commit to the ambitions, report about the progress and continuously take next steps to reduce food waste. The ecosystem holds the leading organisations: businesses (start-ups, SMEs and corporates), governments, NGOs and knowledge institutions.

REFRESH insights and policy advice on how to design effective interventions to reduce food waste at household level have been key in devel-

oping a national social norm campaign. The Dutch government launched the first national strategy to reduce food waste in 2009. A diversity of campaigns and interventions have been implemented since. The impacts of the activities are monitored. Since 2010 a national study into household food waste has been commissioned once every three years by the Ministry of Agriculture, Nature and Food Quality. In 2019 the rate of food waste per person in the Netherlands was 34.3kg: nearly 7 kilos less than in 2016, and a reduction of 29% since 2013 (Figure 2). There has been a particularly strong reduction in wastage of bread, dairy produce, fruit and vegetables, although these food types still have the greatest room for improvement.

The study doesn't definitively show why household food waste has declined, although it does mention factors that could have played a role, such as increased attention to the issue of food waste (84% want to contribute). Dutch people's awareness of the issue appears to be growing, they want to take action and they are being given tools to do so. By buying, cooking and storing food more efficiently, you can prevent a substantial amount of food waste. Solutions are often very simple, such as freezing bread, carefully measuring quantities of pasta and rice to use, using your own senses to check whether milk is still drinkable and storing food in the right place. Also businesses have introduced positive impact interventions and nudges, like a reduction in portion sizes.

An additional positive social norm campaign started in 2019, working with 50 influencers, with the aim to further bring down food waste levels at consumer level. In September 2019 Becky was introduced in order to bring this information to the attention of everyone in the Netherlands.

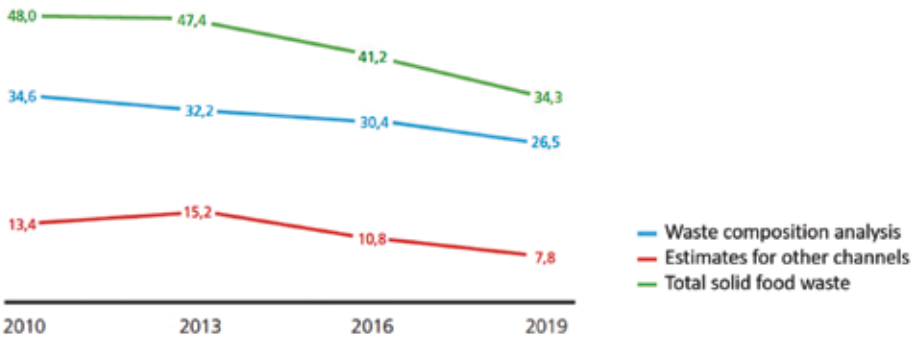

Figure 2. Reduction in household food waste in the Netherlands 2010-2019 (van Dooren, 2020).

This mascot is the face of the campaign 'How #foodwastefree are you?' (or 'Hoe #verspillingsvrij ben jij?' in Dutch). Becky gives people smart tips to help them stop wasting food. Part of the campaign is an annual Food Waste Free Week, an initiative to encourage everybody to apply Becky's tips at home. With the national ecosystem approach and the fact that levels of food waste in Dutch households are decreasing, the Dutch are leading in the challenge to reduce food waste. More effort is needed, for the medium period and long term, building on the important observation that a food waste policy should be integrated in a broader agro and food policy.

The content described in this document is partly based on the REFRESH Policy Brief Reducing consumer food waste (Wunder 2019). REFRESH is funded by the Horizon 2020 Framework Programme of the European Union under Grant Agreement no. 641933.

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III: FOOD LOSS AND WASTE: WHAT CAUSES AND SOLUTIONS EXIST IN LOW AND HIGH INCOME COUNTRIES?

Reducing Food Loss and Waste: 10 Interventions to Scale Impact

Craig Hanson[1]

Background

Reducing food loss and waste is an important strategy to ensure food security and combat climate change. Reducing food loss and waste can increase the amount of food harvested that ultimately gets eaten by people. In addition, reducing the rate of food loss and waste by 50 percent would yield significant reductions in greenhouse gas emissions because more efficient use of food would reduce the need for land conversion for additional food production, slow the rate of increase in fertilizer applications, and reduce methane emissions from food in landfills (Searchinger et al. 2018; Willett et al. 2019). The World Resources Report (Searchinger et al. 2019) and the EAT/Lancet Commission (Willett et al. 2019) both identify cutting food loss and waste rates in half as a critical element in achieving a sustainable future.

What is the food loss and waste challenge?

A significant amount of food intended for human consumption is never eaten. According to the only global data available (FAO 2011), approximately one-third of all food intended for human consumption is lost or wasted between the farm and the plate.

The world is calling to reduce the rate of food loss and waste by 50 percent. The Sustainable Development Goals (SDGs) call for ending poverty and hunger, protecting the planet, and ensuring prosperity for all. SDG 12 seeks to "ensure sustainable consumption and production patterns". The third target under this goal, Target 12.3, calls for halving "per capita global food waste at the retail and consumer levels and reduc[ing] food losses along production and supply chains, including post-harvest losses", by 2030 (UN 2017).

[1] Summary based on *Reducing Food Loss and Waste: Ten Interventions to Scale Impact* (2019). Washington, DC: World Resources Institute. Authors: Craig Hanson, Katie Flanagan, Kai Robertson, Heike Axmann, Hilke Bos-Brouwers, Jan Broeze, Claire Kneller, Dirk Maier, Cassie McGee, Clementine O'Connor, Steve Sonka, Toine Timmermans, Martijntje Vollebregt and Eelke Westra.

What should be done about it?

The report *Reducing Food Loss and Waste: Setting a Global Action Agenda* (Flanagan et al. 2019a) proposed a three-part agenda for tackling food loss and waste (and meeting SDG Target 12.3): (1) the "Target-Measure-Act" approach, (2) an actor-specific "to-do" list, and (3) 10 scaling interventions designed to rapidly scale the deployment of the "Target-Measure-Act" approach and of the "to-do" list.

In *Reducing Food Loss and Waste: 10 Interventions to Scale Impact*, we expand on these 10 scaling interventions by providing a more detailed explanation of what each one entails, why it is important, and what next steps are needed to implement it. Three of the scaling interventions take a "whole supply chain" approach, four of them target specific hotspots of food loss and waste, and three more enhance enabling conditions for reducing food loss and waste.

Whole supply chain approaches

1. Develop national strategies for reducing food loss and waste

Increase the number of countries with national strategies, as these can be an important catalyst for Target-Measure-Act at the country level – aligning public policy, private sector action, and farmer-to-consumer behavior toward a shared goal. A national strategy for reducing food loss and waste is a plan of action for achieving an overall prevention and reduction of food loss and waste within national borders. This plan includes a suite of programs, policies, practices, incentives, and/or other related measures to influence the actions of farmers, companies, consumers, and political bodies in order to achieve the reduction target.

2. Create national public-private partnerships

Increase the number of country-level public-private partnerships dedicated to achieving SDG 12.3. In a public-private partnership, relevant government agencies collaborate with relevant non-governmental actors (e.g., companies, research institutions, civil society organizations) to jointly tackle an issue of joint interest – typically an issue where both public and private actors are needed to affect change. A national-level public-private partnership on food loss and waste is one such partnership where participants share a common ambition to reduce food loss and waste within the country. Participants are ideally national agriculture and environment agencies, food-related businesses (e.g., producers, manufacturers, retailers, restaurants, hospitality companies) active in the country, non-governmen-

tal organizations that work on food loss and waste, and research institutions that bring topical expertise.

3. Launch a "10x20x30" supply chain initiative

Launch a voluntary private sector campaign where at least 10 corporate "power players" commit to Target-Measure-Act themselves and then engage their own 20 largest suppliers to do the same and achieve a 50 percent reduction in food loss and waste by 2030. 10x20x30 leverages the supply chain power of a few companies. Large food retailers and providers have market positions where they have many suppliers, relatively few competitors, and many customers. This is essentially a supply chain "pinch point" with market power. Thus, a handful of retailers and providers can catalyze change "up" the supply chain and across geographies.

Hotspot-specific approaches

4. Invigorate efforts to strengthen value chains to reduce smallholder losses

Invigorate efforts to help smallholder farmers reduce food losses during production and storage. Reducing smallholder losses involves implementing on farm practices and improving the collaboration along the value chain. In other words, smallholders can benefit both from on-farm use of technologies and practices that reduce food loss and from loss reductions downstream from the farm. To achieve effective implementation, well-functioning upstream value chains are needed to support on-farm use and the practices employed need to be consistent with the market needs of downstream value chains.

5. Launch a "decade of storage solutions"

Kick-start a focused collaboration among storage providers, cold chain alliances, financiers, and governments to rapidly get income-sensitive, climate-smart storage technologies into the hands of farmers and distribution networks around the world. A number of solutions for drying, handling, and storage of crops to reduce food loss and waste across the supply chain are emerging (Flanagan et al. 2019a). These include low-cost technologies such as hermetic bags for storage of grains and reusable plastic crates for transportation of fresh produce. Investments in storage infrastructure are growing, too. They include modern warehouses to aggregate grain bags from farmers for "bulk" sales to anchor buyers or cooling sheds to aggregate fresh produce from farmers for "bulk" sales to exporters.

6. Shift consumer social norms

Leveraging the latest findings of behavioral science, engage grassroots campaigns, social media, religious communities, and others to make "wasting food" as unacceptable as littering now is in many countries. Many possible routes exist for changing people's behavior. These include giving people information about an issue, explaining the benefits of changed behavior, adjusting the consumption environment so that change becomes easier, making the desired change the default option, introducing legislation to encourage or mandate the desired change, and leveraging social influence to change behavior (Michie et al. 2013). This scaling intervention is focused on shifting social norms and attitudes, an approach identified as showing potential but currently under-researched with respect to food waste (Stöckli et al. 2019). Shifting social norms may be achieved via a range of actions that target social influences on behavior. By "shifting consumer social norms and attitudes" (hereafter sometimes shortened to "norms"), we mean creating a society in which wasting food is not acceptable, leading to behavior change as a result. In other words, people living in societies where this social norm is currently weak (more commonly in countries and cities of relative affluence) in the future would consider it "unacceptable" to throw away edible food and therefore do not do it.

7. Go after GHG emissions reductions

This intervention calls for two approaches. First, catalyze industry sector-led programs to tackle food loss and waste from those food categories with the highest climate footprints (e.g., beef, dairy, rice). Second, get countries to focus on the reduction of food loss and waste as a contribution to achieving climate goals, for instance by getting food loss and waste reduction into Nationally Determined Contributions (NDCs) to the Paris Agreement on climate change.

Enabling approaches

8. Scale up financing

Scaling up financing for food loss and waste reduction involves increasing the amount of financing available for programs, technologies, and enterprises that prevent or reduce food loss and waste. Such financing could be in the form of grants, government subsidies or incentives, development assistance, loans, or commercial investments. In our view, scaling also needs to involve improving the "bank-ability" or "investment readiness" of reduction programs, technologies, and enterprises.

9. Overcome the data deficit

Over the next five years, a concentrated push to measure food loss and waste is needed to overcome this data deficit in time to support achievement of SDG 12.3. The "data deficit" refers to the current state of insufficient quantified data on food loss and waste levels around the world. With notable exceptions, data is absent or too sparse to be of use (Xue et al., 2017). Of the various studies currently available, many use different scopes. This makes results difficult to compare. Moreover, too few use direct measurement. This ninth proposed intervention is a focused effort over the next five years by governments, companies, UN agencies, and research institutions to generate new quantified data that is more consistent and comprehensive in terms of geographies, stages of the food supply chain, and food categories covered.

10. Advance the research agenda

More research is still needed to answer multiple "next generation" questions that would, in turn, help refine food loss and waste reduction strategies and advance implementation of the global agenda. These questions concern the economics of food loss and waste, how to accelerate technology adoption, how to influence consumer behavior, and more.

A call to action

SDG 12.3 is a historic opportunity for the world to realize numerous food security, economic, and environmental benefits of halving food loss and waste. These benefits support many other SDGs and the Paris Agreement on climate change. Momentum is growing, but the world has much more to do. Only 11 years remain to achieve the targets of the SDGs.

Ten scaling interventions could accelerate adoption of the "Target-Measure-Act" approach to reducing food loss and waste and accelerate adoption of actor-specific interventions across supply chains and geographies. Governments, businesses, farmers, consumers, and everyone in between will need to play their relevant role in implementing these 10 scaling interventions. And they need to do so now because, just like food, there is little time to waste.

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GAIN's Work on Food Loss and Waste Reduction

Teale Yalch and Stella Nordhagen

The importance of food loss and waste for nutrition

The mission of the Global Alliance for Improved Nutrition (GAIN) is to improve the consumption of nutritious and safe food for all people, especially the most vulnerable to malnutrition.[1] GAIN is concerned about food loss and waste because many of the most nutritious foods (e.g., fresh fruit and vegetables, meat, fish, dairy) are perishable and therefore most at risk of being lost or wasted before reaching the consumer. Indeed, a meta-analysis of six selected Sub-Saharan African countries showed that the highest post-harvest losses (without intervention) included fruits and vegetables (56 ± 25%), and fish (27 ± 14%).[2] When nutritious foods are lost or wasted along the supply chain, the total availability of that food in the market is reduced and that reduction in supply can cause prices to increase. As a result, consumers have less access to nutritious food, which is a key contributor to poor dietary diversity and malnutrition. In addition to losses in quantity, there can be losses in the nutritional quality of foods as well as their desirability – which also impacts on consumption decisions.

This chapter argues that addressing this issue requires a greater focus on the middle of the supply chain (i.e., after food leaves the farm or post farmgate) and increased collaboration with private-sector actors via market-based approaches. We provide examples, based on GAIN's work, of how collaboration and market-based approaches can be fostered. GAIN has a rich experience in creating supply chain alliances to improve coordination and collaboration among stakeholders and fostering innovations with real market potential. We conclude by discussing some of the future directions for market-based innovations to reduce postharvest food loss and improve nutrition.

[1] GAIN's Organizational Strategy 2017-2022.

[2] Affognon, Hippolyte; Mutungi, Christopher, Sanginga, Pascal and Borgemeister, Christian (2015). Unpacking Postharvest Losses in Sub-Saharan Africa: a Meta-Analysis. *World Development* Vol. 66, pp. 49-68. Nairobi, Kenya.

The 'missing middle' in food loss interventions

In low- and middle-income countries (LMICs), most food loss and waste occurs along the supply chain from farm to retail.[3] In Sub-Saharan Africa specifically, experts have confirmed that perishable, nutritious foods like fresh produce, meat, dairy and fish are most likely to be lost post-farm gate during the distribution, packaging and processing stages.[4] Despite the concentration of loss of nutritious foods in the middle of the supply chain, a meta-analysis conducted in 2015 showed that over 80% of all postharvest loss studies in their sample focused on on-farm storage improvements for grains.[5] While addressing food loss on farms is critical to achieving Sustainable Development Goal 12.3, there is also a need to better understand the causes of food loss in the middle of the supply chain and to tailor interventions to support off-farm stakeholders in reducing food loss, particularly for nutritious commodities.

GAIN estimates that micro and small- and medium-sized enterprises (SMEs) in Africa produce, process and sell up to 70% of nutritious foods like fresh fruits and vegetables.[6,7] Correspondingly, 80% of African consumers now purchase their food from informal or formal markets. Therefore, the economic success of small-scale farms that produce food largely depends on access to those markets.[8] SMEs provide crucial mid-supply chain services like warehousing, cold storage, logistics, wholesale, processing, and retail services that connect farmers to markets.[9] In recent years, more and more entrepreneurs have capitalized on the opportunity to link food supply to

[3] FAO. (2019). *The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction*. Rome. License: CC BY-NC-SA 3.0 IGO.

[4] M. Sheahan, C.B. Barrett. Review: Food loss and Waste in Sub-Saharan Africa, *Food Policy* 70 (2017) 1-12.

[5] Affognon, Hippolyte; Mutungi, Christopher, Sanginga, Pascal and Borgemeister, Christian (2015). Unpacking Postharvest Losses in Sub-Saharan Africa: A Meta-analysis. *World Development* Vol. 66, pp. 49-68. Nairobi, Kenya.

[6] GAIN. 'Role of SME's in Nutritious Food Supply Chains in Africa', Draft. Expected publication 2020.

[7] AGRA. (2019). Africa Agriculture Status Report: The Hidden Middle: A Quiet Revolution in the Private Sector Driving. *Agricultural Transformation* (Issue 7). Nairobi, Kenya: Alliance for a Green Revolution in Africa (AGRA).

[8] AGRA. (2019). Africa Agriculture Status Report: The Hidden Middle: A Quiet Revolution in the Private Sector Driving. *Agricultural Transformation* (Issue 7). Nairobi, Kenya: Alliance for a Green Revolution in Africa (AGRA).

[9] AGRA. (2019). Africa Agriculture Status Report: The Hidden Middle: A Quiet Revolution in the Private Sector Driving. *Agricultural Transformation* (Issue 7). Nairobi, Kenya: Alliance for a Green Revolution in Africa (AGRA).

demand through innovative and dynamic businesses in these service areas. Yet, a considerable amount of food loss occurs within SMEs working in the middle of the supply chain. The increasing flow of nutritious food through mid-supply chain SMEs represents an important and underutilized pool of actors that can be engaged in the prevention of post-harvest food loss.

Alliances to support food loss reduction: the example of PLAN

In 2016, in collaboration with USAID, GAIN created the Postharvest Loss Alliance for Nutrition (PLAN) program to address challenges SMEs face along the supply chain that cause nutritious foods to be lost or wasted. Through expert consultations and in-depth landscape analyses, GAIN identified three key challenges: lack of coordination among supply chain actors; poor access to the technical expertise needed to adopt improved technologies, particularly cold chain, crating and processing; and insufficient access to the financial resources needed to facilitate this adoption. While a significant amount of food loss occurs on-farm, GAIN found that there were many agriculture organizations making significant progress with farmers to reduce loss on farm and that PLAN would add the most value by supporting businesses post-farmgate. To ensure that holistic and complementary support was provided to all elements of the food value chain, PLAN collaborated with projects that worked directly with farmers.

PLAN was designed to bring together supply chain actors from the public and private sectors to identify underlying causes of loss within a specific supply chain. The actors were supported to co-design and implement relevant solutions to address the local challenges. Under its theory of change, PLAN aims to achieve two primary outcomes: (1) increased adoption, procurement, and application of new technologies and/or new best practices by businesses to reduce post-harvest loss, and (2) improved policies, increased public sector allocation of resources, and private investments in activities that reduce post-harvest loss. These outcomes, in tandem, are expected to reduce food loss, extend the shelf life of target commodities (thereby lengthening the selling season), improve the quality of the target commodities (and thereby their desirability), and improve food safety along the supply chain (also improving desirability). These outcomes, in turn, are expected to lead to increased accessibility, availability, desirability, and perhaps affordability of the target commodity in the market. In the long-term, increased accessibility, availability, and desirability of higher quality nutritious food are expected to lead to increased demand and therefore increase consumption, leading to better nutritional outcomes.

There are several assumptions that underpin PLAN's theory of change, including the existence of appropriate technologies, businesses' willingness to change practices and adopt new technologies, and that selected technologies will have the expected effect when used under real-world conditions. The link to improved nutrition assumes that reductions in loss along the supply chain will lead to increased consumption, and that consumption will improve diet quality. Improvement in diet quality can come about by increased consumption of nutrients (primarily micronutrients) in which the diet was previously deficient, or through the substitution of less nutritious foods (e.g., starchy staples) with fresh fruit and vegetables. Given this complexity, the link between food loss and waste reduction and improved nutritional outcomes has not yet been confirmed in empirical research.

While filling this gap in evidence is essential, the PLAN model offers an example of a promising approach to reducing food loss and waste that targets actors all along the supply chain. To achieve the outcomes laid out above, the PLAN model has three components: improving coordination among actors within a given food supply chain through the Alliance, building capacity and encouraging SMEs to adopt improved practices and technologies through business-to-business (B2B) mentorship, and fostering new innovations in post-harvest loss technology through Innovation Challenges (Figure 1).

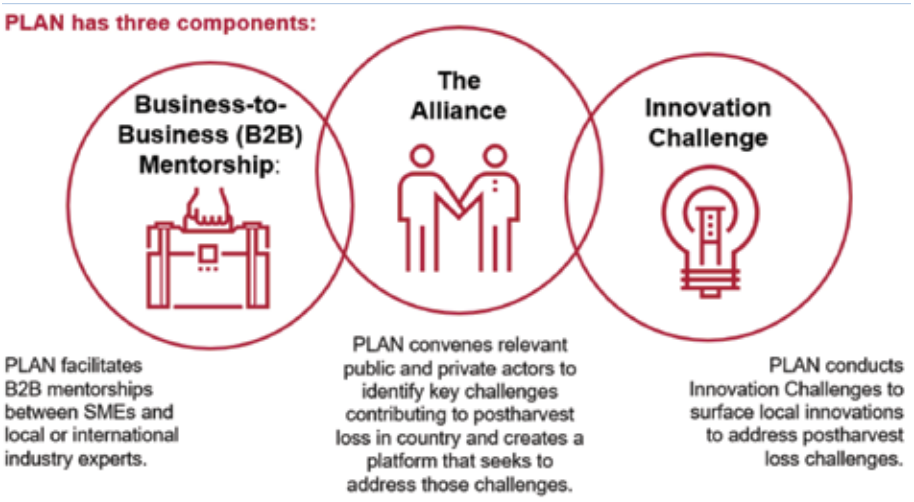

Figure 1. The Three Components of PLAN. Source: compiled by author.

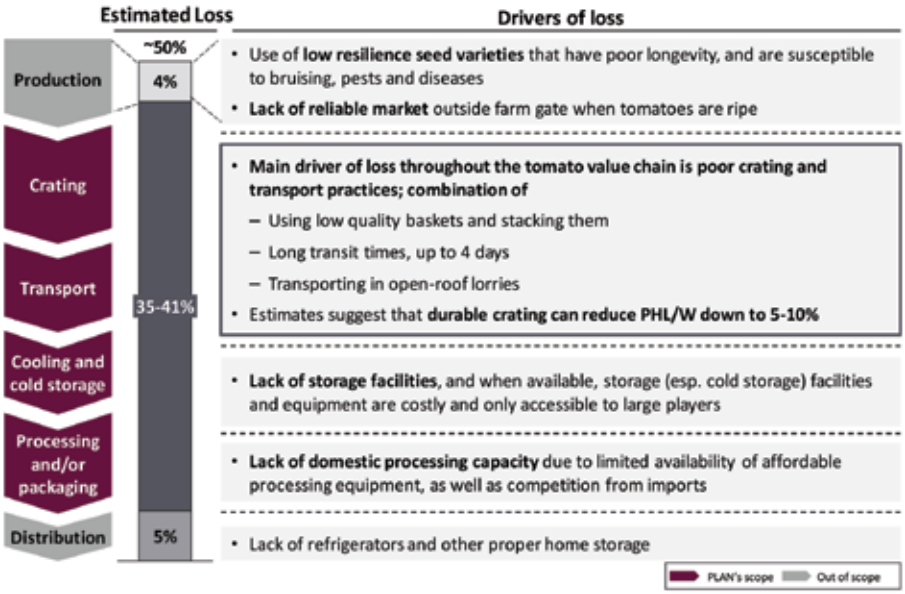

Figure 2. Drivers of loss in the tomato value chain. Source: Dalberg Consulting. (2016). In-depth Landscape Analysis of Nigeria's Tomato Supply Chain. Funded by Global Alliance for Improved Nutrition. Permission for reproduction granted.

As illustrated for the tomato supply chain in Nigeria in Figure 2, a considerable amount of loss happens in the intermediate stages of the value chain due to poor storage and transport, insufficient storage facilities (especially cold storage), and a lack of domestic processing capacity. Many value chains in LMICs display similar weaknesses. PLAN thus specifically aims to build capacity in three technical areas along supply chains for nutritious foods: packaging and crating, cold chain storage/logistics, and food processing.

PLAN is currently being implemented in Ethiopia (with a focus on tomatoes) and Indonesia (with a focus on fish). PLAN closed project-based operations in Nigeria in December 2019 after four years of supporting loss reduction in the tomato value chain; its work is being taken forward under an independent organization, the Organization for Technology Advancement of Cold Chain in West Africa (OTACCWA). The next sub-sections focus in on the Alliance component of the PLAN model, highlighting GAIN's experiences with alliance-building for food loss reduction in Nigeria and Indonesia.

The Alliance

After four years of implementation, it is clear that one of the greatest contributions of the PLAN program has been creating both formal and informal connections between supply chain actors through the Alliance. The Alliance component of PLAN is a cross-sectoral platform for networking and sharing information. Alliance members are stakeholders involved in the target supply chain and include aggregators, logistics companies, cold storage companies, crate producers, market retailers, processors, banks, academic institutions, and government agencies and key government officials. The PLAN Alliance provided an opportunity for private- and public-sector stakeholders to connect, to share knowledge, challenges and experiences, and to work together to address common issues related to post-harvest loss.

Given the informal nature of many supply chains for nutritious foods in LMICs, there are very few organizations, associations or networks that allow businesses working in the same sub-sector (e.g. production, cold storage, processing, or logistics) or with the same commodity (e.g., fresh fruit, dairy, vegetables) to meet, exchange knowledge and create professional linkages. At its core, the Alliance provides the means for supply chain actors to meet likeminded businesses, share market information and build social capital with other relevant actors. Social capital – the connections between individuals and groups and the norms, trust, common values, and shared understandings on which these connections rely – is a critical element of a well-functioning supply chain, particularly where formal institutions are weak. Links between entities upstream and downstream along the supply chain allow actors to effectively identify and address bottlenecks, improve efficiencies, and adequately respond to market demands. As social capital increases within a group so does the flow of information; this helps build individual capacity and the opportunities for partnerships that can lead to collective action.

PLAN Alliances in Nigeria, Ethiopia and Indonesia have helped businesses equip themselves with the tools, knowledge and connections needed to address their specific food loss and waste challenges by creating influential networks that build their social capital. A recent external assessment of PLAN has shown that in Nigeria and Indonesia, the Alliance has fostered private-sector initiative, public-private sector engagement and inter-ministerial collaboration aimed at reducing loss of nutritious foods.[10] The following paragraphs describe these experiences in more detail.

[10] Dalberg Consulting. (2019). 'Assessment of Nigeria Postharvest Loss Alliance for Nutrition (N-PLAN)'. Unpublished report for Global Alliance for Improved Nutrition.

PLAN Nigeria – Encouraging private sector initiative and supporting private-public sector engagement. After several expert consultations, GAIN narrowed PLAN Nigeria's (N-PLAN) focus to the tomato value chain due to the country's high production and loss rates, prevalence of vitamin A deficiency and the government's interest in promoting the commodity. Over the span of four years, N-PLAN created a multi-sectoral alliance with over 230 members[11] from across the tomato supply chain, including traders, growers, aggregators, distributors, local and federal government representatives, banks, cold chain companies, plastic crate manufacturers, and processors. The project team continually communicated, convened and trained members through 17 workshops, summits, and seminars held in seven cities across Nigeria on topics such as cold chain operations, proximate processing and food safety. These capacity-building opportunities allowed stakeholders to adopt technologies such as cold storage units and reusable plastic crates and other best practices. N-PLAN participants interviewed as part of the external assessment reported significant reductions in post-harvest loss, from 35-40% to under 10%.[12]

Not only did the platform create an opportunity for trainings, it also provided a discussion platform for actors from different sectors who would otherwise not be connected. Several stakeholders reported making business deals as a result of relationships developed through their interactions. For example, after meeting at an N-PLAN event, Cold Care (a cold storage manufacturing firm) began leasing cold room space to Fruits and Veggies Global (a fresh fruit and vegetable processing firm) in a transaction worth $12,000 per year to improve food safety and reduce post-harvest loss.[13]

A key outcome of the PLAN Alliance in Nigeria was instigating and supporting the creation of a privately led and funded business association focused on developing the cold chain in West Africa. The Organization for Technology Advancement of Cold Chain in West Africa (OTACCWA) was registered with the Corporate Affairs Commission in Nigeria in 2018. OTACCWA now has over 80 paying members comprised of cold chain professionals, original equipment manufacturers, transporters, logistics operators and refrigeration and air conditioning experts. OTACCWA's mission is to organize the different industry sectors participating in supplying

[11] Including 176 men and 55 women.

[12] Dalberg Consulting. (2019). 'Assessment of Nigeria Postharvest Loss Alliance for Nutrition (N-PLAN)'. Unpublished report for Global Alliance for Improved Nutrition.

[13] Dalberg Consulting. (2019). 'Assessment of Nigeria Postharvest Loss Alliance for Nutrition (N-PLAN)'. Unpublished report for Global Alliance for Improved Nutrition.

the cold chain supply used for perishable agricultural produce and other perishable commodities and represent their individual and collective interests in policymaking, standards setting and industry development.[14]

OTACCWA is recognized by Nigeria's Federal Ministry of Agriculture and Rural Development (FMARD) and has been included as member of its Inter-ministerial Agriculture and Nutrition Working Group. Several organizations, including banks and international organizations, are currently aligning with OTACCWA for cold chain development as a means for reducing postharvest losses and improving effective health services delivery. Additionally, the combined influencing power of OTACCWA and N-PLAN resulted in the Ministry of Agriculture and Rural Development including a dedicated line item for post-harvest loss reduction in their annual budget.[15] GAIN considers the creation of OTACCWA an innovative, market-based outcome that will sustain and advance PLAN's cold chain development objectives for food loss reduction in Nigeria long after the end of the donor-funded project.

PLAN Indonesia – Facilitating inter-government collaboration to address food loss and waste. PLAN in Indonesia (I-PLAN) was designed to focus on fish due to the government's interest in increasing the supply and consumption of fish locally to address high rates of stunting. In order to facilitate I-PLAN's design, GAIN worked closely with the Ministry of Health (MoH) and the Ministry of Marine Affairs and Fisheries (MMAF). By providing a third-party platform through which both ministries were presented as experts, I-PLAN has enabled the two government agencies to collaborate more effectively. A recent assessment of I-PLAN highlighted that one of the project's most critical contributions has been supporting better collaboration between the MoH and the MMAF through government engagement.[16] In Indonesia, it is uncommon for different government agencies to collaborate on joint initiatives. The partnership between the two ministries was facilitated by I-PLAN, which served as an external party capable of taking care of the administrative processes that are required in order for inter-ministerial collaboration to occur. I-PLAN navigated lengthy government approval processes,

[14] OTACCWA Constitution 2018.

[15] Dalberg Consulting. (2019). 'Assessment of Nigeria Postharvest Loss Alliance for Nutrition (N-PLAN)'. Unpublished report for Global Alliance for Improved Nutrition.

[16] Dalberg Consulting. (2019). 'Assessment of Indonesia Postharvest Loss Alliance for Nutrition (I-PLAN)'. Unpublished report for Global Alliance for Improved Nutrition.

a lack of incentive to collaborate, a lack of protocol for how to collaborate and a sense of competition over who 'owns' the successes of the program. I-PLAN was able to avoid these barriers through its role as a third-party program: its successes are seen as the result of both partners' contributions.

The MoH and MMAF are now both board members of the I-PLAN Alliance and have been integral in shaping one of I-PLAN's major annual events: the Innovation Challenge. In 2019, with significant input from the MoH and MMAF, the second Innovation Challenge focused on innovations in food design. The goal was to promote the minimal processing of fish to create healthy fish-based foods or snacks for local consumption. This type of processing is important not only for reducing food loss but also to make fish more available in the market and more desirable to and convenient for consumers.

As a result of I-PLAN's coordination and advocacy, there has been increased activity from government to address post-harvest loss issues, including trainings from District Fisheries Offices (outposts of MMAF) to fish supply-chain actors on post-harvest management and government procurement of post-harvest loss technologies.[17] The MoH and MMAF have also recently signed an agreement – independent of GAIN and PLAN – to promote excellence in Indonesian human capital through increased fish consumption.

Identifying and fostering innovations for food loss and waste reduction

From its inception, PLAN has aimed to promote local innovations to reduce food loss and waste throughout the supply chain. One key part of doing so has been the Business Innovation Challenge, in which a competitive public call is made for innovative new technologies that can respond to an important social need. In 2018 I-PLAN conducted its first Innovation Challenge and received over 230 proposals for technologies that could help reduce the loss of fresh fish; these came from a diverse set of sources – academic researchers, technology entrepreneurs, government employees, and private businesses. A panel of experts then selected four finalists to receive technical and financial support to test, prototype and market their innovation. The four innovations were: Maslaha, a re-freezable plastic ice-pack to replace ice for cooling (also called the 'cold bank'); CoFresh, a fish storage and display unit for motorbikes to be used by last-mile sellers to

[17] Dalberg Consulting. (2019). 'Assessment of Indonesia Postharvest Loss Alliance for Nutrition (I-PLAN)'. Unpublished report for Global Alliance for Improved Nutrition.

replace traditional styrofoam storage boxes; Prominator, a cooling attachment towed by three-wheeled motorbikes to maintain cold chain for fish deliverers; and Coolla, a fiberglass storage box and cooling system, similar in function to a portable refrigerator.

These innovations were all technically promising, but within a market environment, new technologies are only as good as their business model – i.e., the entrepreneurs' plans for making a profit and thereby staying in business so that the innovations can be adopted. A viable business model identifies target customers and competitors and lays out a strategy to meet the demands of the market. To address these needs, I-PLAN provided the Innovation Challenge finalists with not only technical assistance to improve their product but also business support to ensure they adapted the innovation to meet market and consumer demands. Interviews with Innovation Challenge participants indicated that the technical and business support offered to winners gave PLAN's innovation challenge significant added value over other innovation programs.[18] The I-PLAN support also invested in design iteration and consumer feedback – topics that are seldom covered in other innovation programs (particularly those that are government funded). We have found that such support is essential to ensure that innovations are well-tailored to user needs.

With the support I-PLAN provided, the finalists are presently (as of January 2020) working to finalize their designs, increase production, and take their products to the larger market. I-PLAN's support is already yielding positive results. For example, after reducing the size of the cold bank based on user feedback and obtaining the intellectual property rights of the technology, Maslaha sold over 14,400 cold banks to fish supply chain actors in Indonesia from within 6 months. Through the I-PLAN Alliance, Maslaha's owner was also introduced to a new distributor; this partnership has increased the business's reach into new districts and has generated approximately 60% of Maslaha's total sales just within the last 4 months.[19]

In a tropical country like Indonesia, the benefits of ice are fleeting and expensive, and a cost-benefit analysis shows that Maslaha can make economic sense for fish sellers. Fishermen save approximately 1,500 IDR ($0.11) a day on ice by using Maslaha's cold bank and make an additional 2,000 IDR

[18] Dalberg Consulting. (2019). 'Assessment of Indonesia Postharvest Loss Alliance for Nutrition (I-PLAN)'. Unpublished report for Global Alliance for Improved Nutrition.

[19] Dalberg Consulting. (2019). 'Assessment of Indonesia Postharvest Loss Alliance for Nutrition (I-PLAN)'. Unpublished report for Global Alliance for Improved Nutrition.

per kilogram of fish by selling more, faster. Even if they only sell 1 kg of fish per day, their savings thus cover the cost of one Maslaha unit (25,000 IDR/ $1.81) in eight days of use.[20] Maslaha users interviewed in an external assessment also reported that they were sometimes able to sell fish at a higher price, due to the improved quality. Maslaha thus promises to save fish supply chain actors money while also helping to reduce food safety risks and prolong the freshness of fish, thereby reducing loss. Scaling up these types of innovations throughout the supply chain can significantly reduce fish loss – likely eventually resulting in increased supply at a lower cost.

Conclusion: unleashing the potential of market-based approaches for postharvest loss reduction

Finding win-win, economically sustainable solutions such as Maslaha is at the core of market-based approaches to reducing postharvest loss of nutritious foods. In particular, innovations and innovative businesses play a key role in reducing food loss and waste and fostering change in the food system. There is considerable untapped potential in this area.

In 2019 GAIN and the Global Knowledge Initiative (GKI) conducted a study to identify promising innovations in the food system with the potential contribute to improved access to nutritious safe foods. Using the Delphi methodology, GAIN engaged a diverse set of food systems experts to come to consensus on a complex topic. As a result, the experts selected 12 of the most promising innovations for improving nutrition via the food system. As shown in Figure 3, the majority of these innovations are relevant for SMEs working along the supply chain and applicable to food loss and waste strategies. Considerable work could be undertaken to further develop these ideas and bring them to market, supported by viable business plans and in-depth user-oriented market research and iteration. And these are far from the only promising market-based innovations that could have a major positive impact on postharvest loss reduction. Additional efforts to surface locally developed innovations, such as innovation challenges, can serve to identify new ideas that are well adapted to the diverse and challenging physical and economic environments that often influence supply chains for nutritious foods in LMICs.

[20] Dalberg Consulting. (2019). 'Assessment of Indonesia Postharvest Loss Alliance for Nutrition (I-PLAN)'. Unpublished report for Global Alliance for Improved Nutrition.

[21] Hansen, A.R., Keenan, C., and Sidhu, G. (2019). Nutritious Food Foresight: Twelve ways to invest in good food in emerging markets. Global Knowledge Initiative. Funded by Global Alliance for Improved Nutrition.

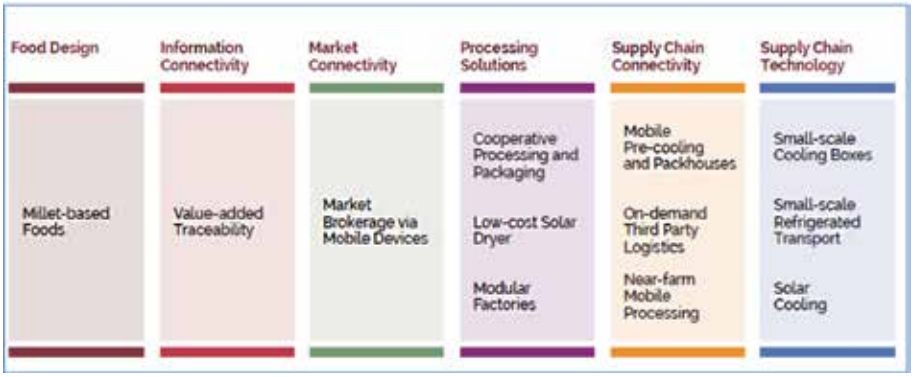

Figure 3. Top 12 Selected Innovations by Technical Category. Source: Hansen, A.R., Keenan, C., and Sidhu, G. (2019). Nutritious Food Foresight: Twelve ways to invest in good food in emerging markets. Global Knowledge Initiative. Funded by Global Alliance for Improved Nutrition. Permission for reproduction granted.

As the experiences of PLAN in Nigeria and Indonesia demonstrate, there is also considerable potential for improving supply chain efficiency and reducing food loss and waste through greater coordination and capacity-building across supply chains. This requires expanding the focus of postharvest loss reduction efforts beyond the farm and into the broader supply chain, forging links and social capital among the key mid-chain actors. Efforts to do this so far have been very limited, with most nutritious food supply chains characterized by information bottlenecks and trust barriers – both of which contribute to loss. In addition to creating PLAN-like alliances in new areas and for new commodities, new endeavors could seek to build coordination and social capital in other ways, such as the use of technology-based platforms to foster transparency.

Future efforts at alliance-building and other approaches for the reduction of postharvest loss to improve nutrition must also invest in collecting data and assessing the impact of the intervention, particularly its effect on nutrition. There is currently scant evidence market-based interventions' ability to reduce post-harvest loss and waste – or whether its reduction results in positive impacts for nutrition. Drawing on the lessons and successes of PLAN, GAIN looks forward to working with the international development community to further contribute to reducing loss and waste of nutritious foods.

Increasing Food System Efficiencies through Coordinated Innovative and Sustainable Food Loss and Waste Reduction Strategies

Lucyna Kurtyka[1]

Introduction

According to the United Nations' Food and Agriculture Organization (FAO), one-third of all food produced for human consumption in the world is lost or wasted, which amounts to $990 billion per year (FAO, 2019a). Food loss occurs along the food supply chain from in-field up to retail. Food waste occurs at the retail and consumption levels (FAO, 2019b).

The amount of available and wasted food varies by country. In the United States, up to 40% of food is thrown away, costing Americans $218 billion/year (NRDC, 2017), and nearly 85% of waste occurs at consumer-facing businesses (supermarkets, grocery stores, restaurants, cafeterias, etc.) and homes (ReFED, 2016). Food waste is the largest component of landfills, which are the third largest source of methane (USDA, 2015). According to a study by Spiker et al. (2017), in 2012 the amount of food discarded in the United States at the retail and consumer levels alone could have provided 2,000 kcal/day to 84% of the US adult population. The authors analyzed the loss of vitamins A and E, calcium, magnesium, iron, and fiber. They estimated that, for example, the amount of wasted dietary fiber could have filled the gap of underconsumed dietary fiber (i.e., the difference between the Recommended Dietary Allowance and the actual intake) for 206.6 million adult women. The authors also recognized that only a portion of this nutritional value could be recovered for human consumption.

In addition to loss of nutrients, food losses and waste represent a waste of valuable resources used in production such as land, water, energy, agricultural chemicals and labor, which puts significant strains on the environment,

[1] The author is Senior Scientific Program Director at the Foundation for Food and Agriculture Research (FFAR; www.foundationfar.org) – a nonprofit organization established by US Congress in the Agricultural Act of 2014 known as the Farm Bill.

economy, and society. According to the High-Level Panel of Experts (HLPE) on Food Security and Nutrition of the Committee on World Food Security, the extent of food loss and waste (FLAW) means that it should be considered not an accident, but an entrenched component of food systems. FLAW is the consequence of the way food systems function technically, culturally, and economically (HLPE, 2014). The prevention of FLAW not only can save food itself, but can also lead to economic, environmental and social benefits, while contributing to food security and helping mitigate climate change.

FLAW has been gaining worldwide attention from governments, food manufacturers, retailers, and nonprofit organizations. Numerous policies, strategies, and practices have been developed and applied across the globe to reduce food waste and redirect surplus food to improve food security, reduce food costs and benefit the environment. In September 2015 the United Nations (UN) General Assembly adopted a set of 17 Sustainable Development Goals. Goal 12 seeks to "ensure sustainable consumption and production patterns". The third target under this goal (Target 12.3) calls on all nations to "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" by 2030 (UN, n.d.). The same month the UN Sustainable Goals were adopted, the US government set the first ever national goal for food waste reduction at 50% by 2030. This effort, led by the US Department of Agriculture (USDA) and the US Environmental Protection Agency (EPA), seeks to work with communities, organizations and businesses along with state, tribal and local governments (USDA, 2015; EPA, n.d.).

Challenges and research opportunities

The food system is global, highly complex and constantly evolving. It involves interactions among humans, resources, and environments that are part of food production, storage, distribution, and disposal (Figure 1). However, the food production system also generates by-products and food waste. Changes made to one element of that system may intentionally or unintentionally impact others. The food system faces numerous challenges, such as climate change and loss of arable land, changes in dietary preferences and consumer attitudes toward food production, and new delivery systems. Systems approaches are needed to better understand and evaluate these interactions and to develop effective and sustainable innovations (both technological and non-technological) aimed at increasing the availability of nutritious food while reducing FLAW.

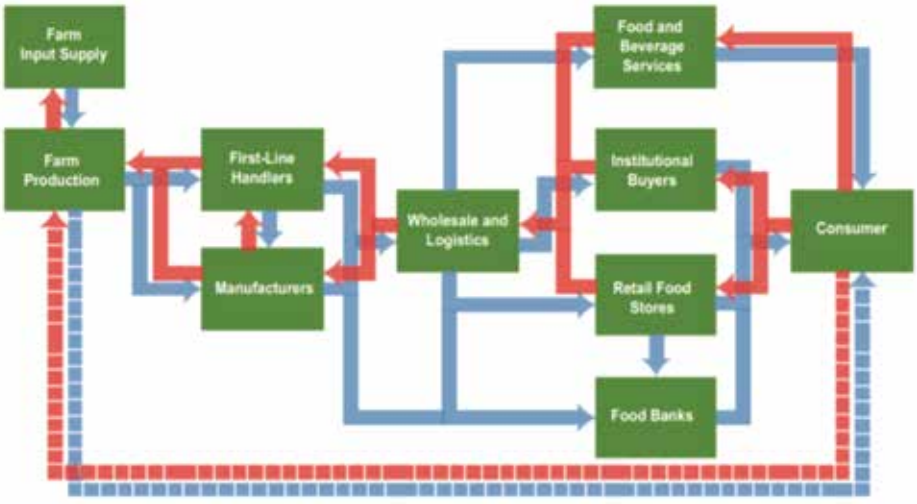

Figure 1. Conceptual model of a food supply chain. Elements or actors in this supply chain in one area (e.g., region or country) also have interactions (e.g., international trade) with actors in other areas. Reprinted with permission from A Framework for Assessing Effects of the Food System (2015) by the National Academy of Sciences, courtesy of the National Academies Press, Washington, D.C.

Reducing FLAW should be a priority in establishing more sustainable patterns of food production and consumption. It is imperative to increase efficiencies in agricultural and food production not only to address food supply needs associated with an increasing global population, but also to address increasing nutrient and fiber demands. Achieving these goals will require a forward-looking, holistic and transformative approach to the food system that integrates different perspectives, including those outside the traditional food and agriculture groups.

Because the FLAW problem is such a multifaceted complex issue, it is often challenging to define top priorities for research or interventions. So far, approach to FLAW has been fragmented. Multiple entities work to address this issue, each focusing on a different segment of the food system. Often, this work is not coordinated with other groups.

Science plays a prominent role in building and transforming the world, and its role cannot be overstated in tackling FLAW. It allows not only the development of a robust knowledge base, but also the pursuit of technological and non-technological solutions. Science provides an undisputable and objective basis for developing creative policies and mechanisms to fos-

ter innovation and enable entrepreneurship. Scientific partnerships bring together diverse groups representing different disciplines and perspectives across the food system, allowing them to develop and work toward common goals while sharing resources and responsibilities. Science ensures a holistic approach to the issue.

Overall, groundbreaking research is needed on sustainable FLAW reduction to decrease negative environmental impacts of that loss and waste, and forge greater food security. Questions to be considered when organizing research on FLAW include:

- Which challenges could be addressed by research? Are there proof-of-concept projects that could be conducted to help scale up promising approaches to reducing the generation of wasted food?
- Which challenges should be tackled first?
- Which research projects would have the greatest impact on reducing food waste through prevention and food rescue? In other words, what is a game changer?
- What stakeholders would need to be involved in scoping or implementing research?
- What research questions are not being answered and why?
- What research questions are being answered within different disciplines or contexts that could be applicable to addressing FLAW?
- How can we better frame and scope research to answer questions that drive action?
- What are the different ways that we could categorize research to identify gaps, commonalities, and opportunities?
- What stakeholders would need to be involved in scoping or implementing the research?
- How to measure success?

When developing a research agenda aimed at reducing FLAW, socio-economic factors must also be taken into consideration. Economic status, food preferences, habits, emotions, and interpersonal interactions are among factors that contribute to food waste generation in homes. Another factor in discarding safe food is confusion around food labeling, such as "best by" date. Retail can waste high volumes of food that is safe and edible because products do not meet customer demands around variety, consistency and freshness, or because the product was overstocked, no longer meets appearance standards or has damaged packaging. In the case of restaurants, the type and amount of generated food waste depends on the restaurant model. An example is a quick-service restaurant where food is less commonly

consumed on the premises compared to full-service restaurants. Unlike retailers, the biggest issue for restaurants is that most discarded food consists in consumer 'leftovers', which, for safety reasons, are no longer consumable (FWRA, 2016).

Recognizing the importance of different stakeholders working together to address challenges faced by the food system, in 2014 the US Congress established the Foundation for Food and Agriculture Research (FFAR; www.foundationfar.org) in the Agricultural Act known as the Farm Bill. FFAR was created to support food and agriculture research, foster collaboration, and advance and complement the mission of the US Department of Agriculture. The premise of FFAR's formation was that increased investment in cutting edge research and development, through public-private partnerships, would be critical to nourishing a growing global population.

That is why in 2019 FFAR, together with the Rockefeller Foundation, co-funded the Consortium for Innovation in Post-harvest Loss and Food Waste Reduction where thought leaders and experts from across the globe work together with industry and nonprofit organizations to address social, economic and environmental impacts from FLAW. Participating institutions include Iowa State University, USA; University of Maryland, USA; Wageningen University and Research, Netherlands; Zamorano University, Honduras; University of São Paulo, Brazil; Stellenbosch University, South Africa; University of Nairobi, Kenya; Kwame Nkrumah University of Science and Technology, Ghana; and the Volcani Center, Israel. The Consortium works collaboratively to develop a scalable approach for adoption of the Rockefeller Foundation's YieldWise model to provide farmers in developing and developed countries with cost-effective strategies and technologies that link their crop supply to market demand. This will allow farmers to gain more value from their crops and become more profitable, while stimulating local economic growth and improving the resiliency of rural communities. In addition to developing strategies to reduce FLAW, the Consortium is building the academic and entrepreneurial capacity of the next generation of scientists by engaging researches and students in multi-national multi-disciplinary teams in the project identification, planning and execution phases together with professionals from the private and public sectors.

Food waste is often interconnected with packaging waste, yet both issues are often viewed as at odds with one another. The core purpose of packaging is to protect and extend the life of food, making sure it arrives fresh and intact to store shelves and our homes. At the same time, packag-

ing, particularly plastic packaging, has been receiving increased attention from food businesses, nonprofit organizations, policymakers and consumers due to end-of-life waste management concerns. The Foundation for Food and Agriculture Research is spearheading a Food Packaging Prize to identify and accelerate the most promising packaging solutions related to food waste. Expected outcomes from this initiative include:

- Innovative food packaging materials and/or technologies that replace currently used packaging (polystyrene foam trays, plastic clamshells, freezer wrap, etc.) and meet the highest sustainability, food safety, and food quality criteria adopted and integrated into the food value chain.
- Increased collective knowledge around optimizing the intersection between food waste reduction and packaging material sustainability to reduce costs and environmental impacts across the food system.

The Prize will also foster competition and build momentum to support scientific breakthroughs, from concept to prototype development, to provide practical solutions for the food industry and retailers.

In summary, the number of improvements aimed at reducing FLAW or recovering food that otherwise would go to waste has been growing, but more is needed. Technical and non-technical innovations, innovative processing technologies, and online platforms are needed to help reduce food waste or divert it from landfills on a large scale from farm to the consumer. At the same time, to take full advantage of the benefits these innovations could offer and see their impact, they would have to be widely adopted across the food system.

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Optical Technologies for Improvement in Food Security

Kate C. Blanco, Thalia Q. Corrêa, Shirly M.L. Perez, Bruno Pereira de Oliveira, Vanderlei S. Bagnato[1]

1. Introduction

Risks to food security happen during all phases of food preparation, storage, transportation, distribution, and sale, under any condition: raw, cooked, chilled, at room temperature, or kept warm – whether exposed or not – for consumption [1].

Chemical, physical, or biological aspects can alter the organoleptic properties of food, often causing the appearance of lethal substances for allergic individuals, or even producing bacteria, viruses, fungi, protozoa, and toxins, which are often pathogenic, making food unfit for consumption [2].

The relative number of microorganisms or even the presence of pathogenic strains in food affects microbiological quality, which is a factor causing infectious diseases and pertains to the importance of controlling contamination – as described – in order to guarantee food security. Figure 1 shows the most common microbial agents that cause foodborne diseases. Microbial resistance to existing antimicrobials is a growing food security problem – serotypes of *Salmonella typhimurium*, *Campylobacter spp.*, *Shigella spp.*, *Vibrio spp.*, *E. coli* can be cited in this context. The severity of these diseases in humans can vary from mild symptoms to health risk conditions [3].

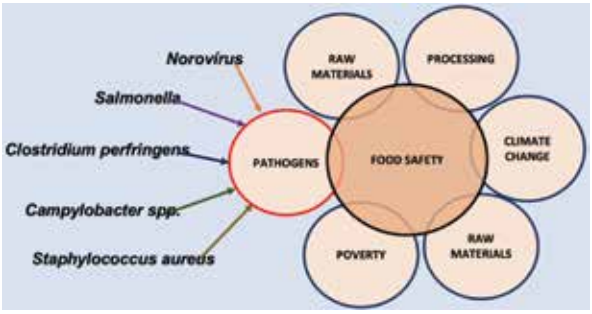

Figure 1. Food security and the main pathogens that cause disease transmission through food. Source: compiled by author.

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Considering the cumulative effects on humans, the use of chemical substances used in hygiene, disinfection or decontamination to control microbial contamination in food can threaten the population, exposing it to the danger of cellular mutations that cause cancer [4].

2. Alternative optical-based technologies for the food loss problem

2.1. Ultraviolet illumination

Ranges of ultraviolet (UV) radiation from 100 to 400 nm are variable for the inactivation of each microbial type and species. UV light induces damage to DNA molecules that can lead to mutations or cell death. Viruses and bacteria are more easily affected by UV-C radiation at 254 nm. Higher doses of UV-C used for inactive protozoa such as in the case of helminth eggs, are overdoses. The absorption of UV-C photons in the nitrogenous bases of DNA results in the reduction of the dimerization of the pyrimidine bases [5].

Thermal and acidic inactivation of microorganisms are options used to decontaminate fresh vegetables. These acidic pH solutions are effective in achieving a reduction in the number of pathogens. However, they cause an environmental pollution problem. Food geometry can be a problem for penetration of UV-C rays if these cannot reach the entire surface where the microorganisms are attached. The circulation of water in a reactor with the volume passing at a precise distance from UV-C light may inactivate microorganisms.

The Optics and Photonics Research Center (CEPOF) in São Carlos, São Paulo, Brazil, described the construction of a reactor in Oliveira *et al.* [6] with several UV-C emitters distributed to improve homogeneous lighting of fresh broccoli and increase their microbiological quality (Figure 2). The circulation of UV-water in this system, in addition to removing the microorganisms contained in the vegetables, can destroy microorganisms in food when it passes through the light. Water volume in this system is reduced, causing no problems to the environment and not even the accumulation of toxic substances in food. Microbial inactivation in fresh broccoli by this system was effective without resorting to standard use, which is the solution using chemical substances.

In another study, Corrêa *et al.* [7] demonstrated the decontamination of meat and fruit using a new device with UV-C lamps distributed above and below the food. UV-C radiation eliminated part of the microorganisms on the surface of these foods, and the most effective result was achieved in apples, with reductions of 3.2 ± 0.4 and 3.8 ±

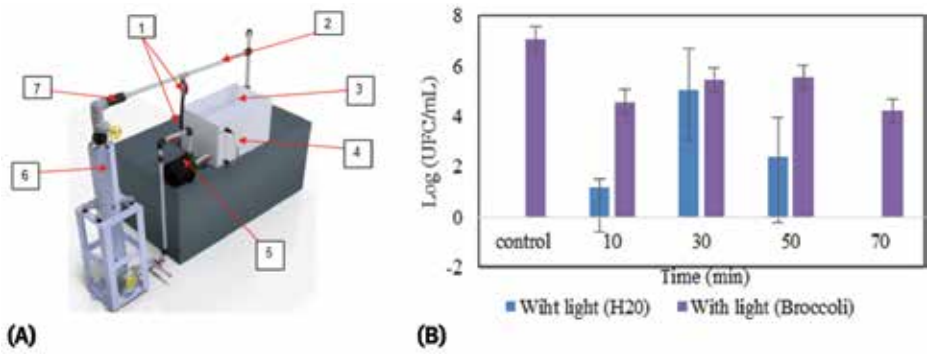

Figure 2. (A) Representation of the water circulation reactor in UV-C: (1) speed control of water that passes through the UV-C light reactor; (2) exit and return piping for washing; (3) broccoli washing tank; (4) water measurement system; (5) pump for circulation; (6) UV-C light reactor and its components; (7) connections to the piped reactor system. **(B)** Analysis of the leaching of broccoli in the water with UV-C light. Source: compiled by author.

0.2 log CFU/mL after 5 and 10 min of UV-C irradiation, respectively. Moreover, since UV-C irradiation only takes a few minutes to reduce microbial contamination, the physicochemical and nutritional qualities of the foods were preserved.

2.2. Ozone

Ozone gas is well known for its antibacterial activity and, although toxic, it quickly dissociates into oxygen. Ozone is widely used to inactivate microorganisms in solution. The mechanism of action in bacterial cells occurs through the oxidation of unsaturated lipids in the cytoplasmic membrane that overflows the contents of the cell in addition to oxidizing proteins, enzymes, and nucleic acids.

Among the techniques most used today to preserve food for sale, only refrigeration paralyzes the growth of microorganisms, decreasing their metabolism.

Concerning food safety with minimal processing for the commercial valorization of the product, CEPOF has been developing new equipment with designs capable of delivering ozone in gaseous and liquid form, in addition to acting in conjunction with UV to reduce the microbial load of meat, thus ensuring that this food reaches consumers with quality intact.

The efficiency of ozone gas in concentrations of 11-15 ppm was tested in steel and meat samples, the microbial inactivations were significantly

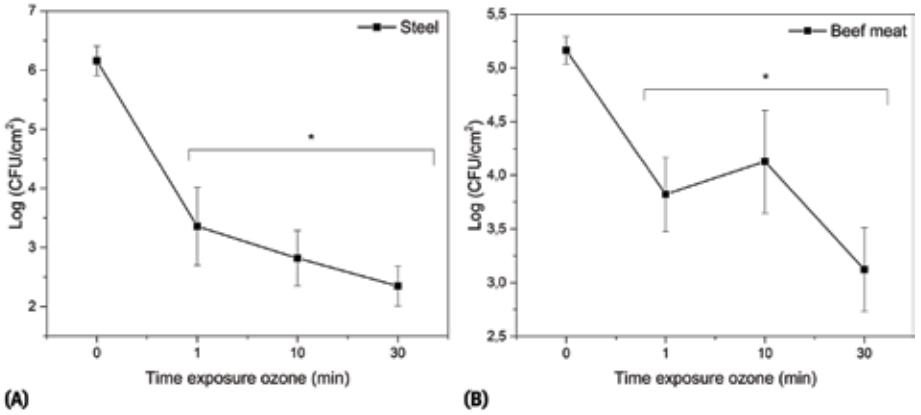

Figure 3. Evaluation of gaseous ozone: **(A)** decontamination of steel surface contaminated with E.coli, **(B)** decontamination of beef meat samples with *in natura* contaminations in times of exposure to ozone of 1, 10 and 30 minutes. *Significantly different from control ($p < 0.05$). Source: compiled by author.

different ($p < 0.05$), obtaining for steel samples reductions about 3,9 Log of *E.coli* in 30 minutes (Figure 3A) and for meat samples 2 Log of *in natura* contaminations (Figure 3B). These results showed the potential of ozone for microbial inactivation in different types of samples.

2.3. Photodynamic inactivation

Photodynamic inactivation (PDI) is a technique based on the simultaneous interaction of photosensitizer (PS), considering its non-toxic concentration of light at a specific wavelength for its absorption by PS, and oxygen (O_2), generating reactive oxygen species capable of disrupting pathogenic microorganisms of various species and strains. PDI has been introduced as a promising approach to food decontamination.

CEPOF has studied curcumin, used as a food additive, as a PS in the decontamination of different types of meat and fruits. An article by Corrêa *et al.* [7] describes protocols using curcumin, capable of reducing pathogenic microorganisms in food. PDI reduced microorganisms in beef and chicken by 1.5 ± 0.2 and 1.4 ± 0.2 log CFU/mL, respectively, using 40 μM curcumin and 15 J/cm² of light dose at 450 nm (Figure 4A). The most effective result was achieved in apples, with a reduction of 2.0

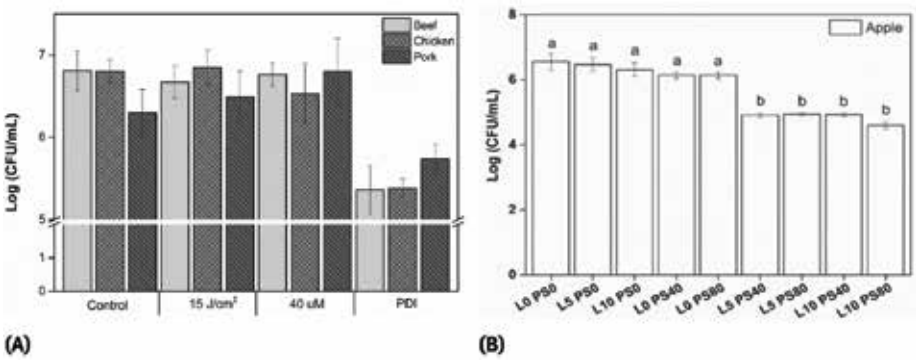

Figure 4. (A) Log CFU/mL of *S. aureus* in meats after curcumin-mediated PDI treatments. **(B)** Log CFU/mL of *S. aureus* in apple after curcumin-mediated PDI treatments. Cur: 40 and 80 uM. Light doses: 5, 10 and 15 J/cm2. Incubation time: 30 min. Source: compiled by author.

± 0.4 log CFU/mL, using 80μM curcumin and 10 J/cm^2 of light dose (Figure 4B).

PDI showed antimicrobial effect in food, being useful to reduce bacterial contamination levels on the surface of meats and fruits. The surface properties of the food may influence the decontamination success, since microorganisms occurring in crevices on the surface of the food are shielded from the light. However, one strategy to maintain the effectiveness of PDI would be use a light array that spreads evenly over the entire surface of the food to be decontaminated.

3. Conclusion

In general, finding solutions for food decontamination using new optical technologies is a new and very promising area. Both the use of ultraviolet light and the use of visible light with photodynamic action are techniques based on photo-reactions that inactivate biological contaminants in food quite adequately. The most important feature of these techniques is that they do not modify the basic characteristics of the food or offer risks to those who consume it. These techniques are inexpensive, and highly secure. On the other hand, the use of ozone is quite efficient and constitutes an already established clean method, which is minimally aggressive to the environment and quite efficient in combating contaminants. These modern, more technological techniques are an encouragement to solve the current situation of food losses caused by contamination.

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Tackling Food Loss and Waste with a Global Science Consortium

Dirk E. Maier,[1] **Steve Sonka,**[2] **Toine Timmermans,**[3] **Cassie Welch McGee,**[4] **and Kyle Poorman**[5]

Food loss and waste (FLAW) is a global problem that negatively impacts the bottom line of businesses and farmers, wastes limited resources, and damages the environment. The Foundation for Food and Agriculture Research (FFAR), The Rockefeller Foundation, Iowa State University (USA), University of Maryland (USA), Wageningen University and Research (The Netherlands), Volcani Center (Israel), Zamorano University (Honduras), Stellenbosch University (South Africa), University of São Paulo (Brazil), University of Nairobi (Kenya), and Kwame Nkrumah University of Science and Technology (Ghana) have partnered to establish the *Global Consortium for Innovation in Post-Harvest Loss and Food Waste Reduction*. Through this Consortium, thought leaders and experts from across the globe work in tandem with industry and nonprofit organizations to address social, economic and environmental impacts caused by FLAW. The Consortium's agenda is focused on preserving nutrients, improving livelihoods, and realizing an efficient food system.

Feeding a growing global population nutritious food demands innovation at all levels – from planting to processing to consumption. The Consortium works with farmers, small and medium enterprises (SMEs), and other stakeholders throughout the global food supply chain to use scientific knowledge, practical technology, applied research, and innovative entrepreneurship to manage and steward resources effectively and efficiently. Optimizing food production and preservation practices is critical for ensuring that farmers are profitable, nutritious food is plentiful and accessible, and the environment is protected.

The mass of food moved globally is enormous. The World Bank estimates that annual value of the global food system at approximately $8

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[2] Emeritus Professor and Consortium Associate Director, University of Maryland.
[3] Research Engineer and Consortium co-PI, Wageningen University & Research.
[4] Consortium Program Manager, Iowa State University.
[5] Consortium Communications and Policy, Iowa State University.

trillion (van Nieuwkoop, 2019) or approximately 10% of the annual value of the global economy. According to FAO, 4 billion tons of food is produced annually, and 1.3 billion tons is lost or wasted. Much of this food is lost in the initial steps of the food value chain, which makes the logistics of the first mile from harvest to the initial preservation point critical in mitigating FLAW. For example, more than 40% of fruits and vegetables in lower income countries spoil before they can be consumed, affecting producers, manufacturers, distributors, and consumers. These include mangos, avocados, pineapples, cocoa, and bananas – all of which are in high demand and imported by medium- and high-income countries. These fruits and vegetables are also essential to a healthy and nutritious diet. Preserving healthy foods has significant direct and indirect economic benefits and could have profound impacts for countries throughout the development spectrum. For example, the availability of healthy foods in the United States has been linked to increased life expectancy and reduced instances of chronic, non-contagious diseases (Bell et al., 2013). Additionally, these studies have often been conducted in the context of community access to markets that sell healthy vegetables. In the United States, low income and minority communities are often underserved, resulting in poor health outcomes because of limited access to healthy food (Bell et al., 2013). The ability to reliably service communities around the world with healthy foods will depend on the ability to build efficient food value chains that preserve more nutrients by reducing loss and waste and building better supply chains. Healthier diets will translate into lower healthcare costs, as well as increased sellable fruits and vegetables that will benefit farmers and businesses throughout the food supply chain.

Post-harvest loss (PHL) and food waste (FW) negatively impact the bottom line, especially that of smallholder farmers (SHF) who are not compensated for spoilage or loss of their products. Consequently, consumers have reduced access to certain foods or must pay a higher price. Additionally, FLAW forces farmers to use precious natural resources producing food that either never makes it to the supermarket or is otherwise thrown out by consumers due to short shelf-life or quality issues, creating a significant drain on environmental resources.

The Consortium approach focuses on building academic and entrepreneurial capacity by engaging researchers and students in multi-national, multi-disciplinary teams for project identification, planning, and execution phases, together with experts and entrepreneurs from the private and public sectors. The Consortium aims to:

1. Advance a common, collaborative research agenda focused on deploying member expertise across the global food system.
2. Enhance academic and entrepreneurial capacity of the next generation to deliver nutritious foods and ensure food security.
3. Develop practical approaches to measure value chain loss and waste.
4. Increase efficiencies in the global food system to sustainably preserve nutrients.
5. Achieve sustained, scalable implementation of appropriate methods to preserve, process, package, and transport nutritious foods.

The remainder of this chapter highlights Consortium research projects that are impacting FLAW across sub-Saharan Africa.

Mobile processing facilities for perishable crops

Bert Dijkink and Jan Broeze[6]

Consortium scientists from Wageningen University and Research, through their affiliation with CGIAR's research program on Climate Change, Agriculture and Food Security (CCAFS), have analyzed loss and greenhouse gas (GHG) emissions associated with different types of cassava processing methods in Mozambique. Mobile processing facilities have previously been identified as a key innovation and intervention technology for reducing FLAW (Farley et al., 2017), and it is anticipated that the results will be applicable to other perishable crops and locales.

The study compared three configurations for supplying cassava to a facility and demonstrated that, for such a highly perishable crop, a mobile processing facility was by far the best loss reducing option. Mobile processing cut PHL of cassava to 15% from 40-50% found in traditional village-level processing and processing in a centralized regional factory. This represents a 67% PHL reduction due to mobile processing. Additionally, GHG emissions were reduced by 20% and 40% compared to importing starch products and large-scale centralized processing. Reasons for the gains realized are just-in-time harvesting and delivery of cassava in the vicinity of the mobile processing facility, and reduction of energy and other costs for transporting water in raw cassava from fields to a regional processing factory, compared to transporting shelf-stable starch products.

[6] Wageningen University & Research.

Consortium members have initiated life-cycle analysis projects to evaluate the potential of mobile processing facilities to reduce PHL and GHG emissions, and increase profitability of SHFs and SMEs in several additional value chains and countries, including oriental vegetables in Honduras, cassava in Ghana, and mangos in Kenya.

YieldWise Initiative value chain analysis

Consortium researchers have been studying key aspects of The Rockefeller Foundation's YieldWise Initiative with a focus on identifying and communicating lessons learned based on the substantial amount of data gathered and developing a predictive model to quantify PHL of perishable crops.

YieldWise Initiative background

In 2016 The Rockefeller Foundation launched the YieldWise Initiative aimed at reducing PHL in lower income countries (i.e., Kenya, Nigeria, Tanzania), and FW in the United States. In sub-Saharan Africa (SSA), YieldWise provided SHFs and SMEs with access to segmented markets, financing, and technologies and solutions that curb preventable crop loss, and facilitated training that helped them solidify agreements with local, regional and national buyers.

The YieldWise Initiative incorporated the following four action pillars:

1. Access to technologies: promoting the adoption of appropriate loss-reducing technologies.
2. Access to finance: collaborating with financial institutions to develop credit products that can be accessed by farmers and farmer-based organizations.
3. Aggregation and training: training farmers and other supply chain actors in post-harvest management and facilitating development of local aggregation centers.
4. Access to markets: stimulating demand by engaging actors across the diverse ecosystem of buyers.

Across these pillars, as appropriate, the YieldWise Initiative engaged both the private sector as key partners and government entities for collaboration. Initial results were encouraging, indicating loss reduction of between 20-30 percent, according to maize and mango catalytic demonstrations. The YieldWise Initiative engaged approximately 200,000 farmers in Kenya, Tanzania, and Nigeria. This also contributed to a high uptake and utilization of loss-reducing technologies and practices across the three value

chains: maize, mango, and tomato in Tanzania, Kenya, and Nigeria, respectively.[7]

YieldWise Initiative lessons learned in the mango value chain

Steve Sonka and Rajshree Agarwal[8]

The Consortium has been analyzing the entirety of the YieldWise Initiative through a set of after-action follow-ups with stakeholders of the three value chain interventions. This analysis has led to the development of a set of lessons learned. An initial set of lessons was derived from the findings of intensive qualitative, in-person interviews held in 2019 with stakeholders of the Kenyan mango sector. Ultimately, the findings emphasized the value of a more comprehensive systems approach when attempting to implement and subsequently understand the contributions of value chain interventions. A key premise of the YieldWise Initiative is that effective interventions need to extend beyond technology provision. The lessons learned are summarized in detail in another chapter of this publication (Measuring to Manage by Steve Sonka).

YieldWise Initiative predictive model to quantify PHL

Hory Chikez and Dirk E. Maier[9]

The Consortium has access to all qualitative and quantitative PHL data of the YieldWise Initiative projects. This data was collected by TechnoServe, AGRA, and PYXERA Global when these entities carried out respective project work in Kenya, Tanzania, and Nigeria. The data for the mango value chain has been analyzed in-depth to develop a better understanding of the impact and interactions of interventions on PHL in Kenya. As a result of the analysis, Consortium researchers have developed a statistical approach to quantify the most effective interventions and developed a predictive model that can quantify PHL as a function of combining multiple interventions along the value chain from harvest to local market, wholesaler, processor, or exporter. The aim of this research is to enable a consistent approach to identify key parameters for which PHL data should be collected. These parameters will then be utilized to develop predictive models for use as an online tool by stakeholders in various food supply chains. This modeling approach will enable the

[7] https://www.rockefellerfoundation.org/our-work/initiatives/yieldwise/
[8] University of Maryland.
[9] Iowa State University.

stakeholders to refine their operations and reduce PHL by evaluating various post-harvest and supply chain practices. Additionally, Consortium members will utilize the approach for PHL data collection and the predictive tool to evaluate other value chains and countries.

Measuring climate impact of food choices

Jan Broeze and Toine Timmermans[10]

As collaborators of the CGIAR research program CCAFS, Wageningen University and Research scientists analyzed food choices regarding GHG emissions associated with ingredients and food waste for three typical meals at an international conference. This study analyzed menu offerings over three days as a practical demonstration in using their method to analyze how food choice impacts overall GHG emissions. They demonstrated substantial differences among menu choices with regard to GHG emissions of the associated food ingredients arising from food wasted by conference participants. The CO_2 equivalents (CO_2-eq.) for the highest impact dish (Rendang meat dish) per kilogram (kg) of food had approximately 11 kg of CO_2-eq. of greenhouse gases associated with it, which was more than 10 times higher than for the lowest impact dish (Rendang meat replacer) at 1 kg of CO_2-eq. Therefore, menu offerings, whether at an international conference, a factory canteen, a school cafeteria, or a family household, have high variability of GHG emissions because of ingredients used and the potential for food waste. Food choices can therefore significantly impact climate.

Hermetic storage bag technology standards

Cristine Ignacio and Dirk E. Maier[11]

The value of hermetic storage bag technology for preservation of grain quality has been well documented. However, there is not yet an internationally accepted engineering standard that defines material properties and performance parameters for hermetic storage bags. Currently, all commercial suppliers self-proclaim to offer hermetic storage bags. Consortium researchers are in the process of assessing and testing the engineering properties of different types of commercially available hermetic storage bag products. This testing is in an advanced stage with most engineering properties already quantified. Once complete, the assessment and associated

[10] Wageningen University & Research.
[11] Iowa State University.

publication of data will allow the Consortium to contribute to the establishment of an international standard for hermetic storage bag technology. This standard will codify the properties a storage bag will need to have in order to be certified as hermetic and ensure purchasers that a hermetic storage bag product meets a rigorous international engineering standard.

Digitalization of food supply chains

Shweta Chopra[12]

Consortium scientists have evaluated several case studies on digitalization of food supply chains. These case studies demonstrate the promise and drawbacks of the current state of digital integration in food supply chains.

Modern agriculture practices have increased the yield of food production; however, surplus yields often do not reach the people who are in need, due to the lack of effective supply chains and logistics. As a result, it leads to food insecurity in certain geographical areas and FLAW in others. In recent years, due to digitalization, stakeholders can connect with each other to create an effective supply chain. In agriculture supply chains, digitalization provides an opportunity to link stakeholders, such as farmers, processors, and distributors, in one platform, which provides a means to (i) effectively monitor agriculture production, (ii) make informed decisions regarding the processing, storage, and distribution of agricultural products, (iii) help with tracking and tracing the movement of food which is essential at the time of a food safety recall, and (iv) track consumption patterns in different geographical regions. However, complete digitalization of supply chains is a huge challenge. The Consortium looked at six different cases where digitalization is transforming supply chains by providing the ability to monitor and make decisions but are not completely integrated. We have included one of the short cases below and the others are available on the Consortium blog.[13]

Case 1: Due to increases in affordability and accessibility of cloud computing, open-source software, and other digital tools in recent years, digitalization has begun to make positive impacts on various agricultural supply chains in Africa. For example, Zenvus[14] is a Nigeria-based precision agriculture Information and Communication Technology (ICT) platform that helps farmers measure and analyze soil temperature, nutrient content,

[12] Ohio University.
[13] https://www.reducePHL.org/
[14] https://www.zenvus.com/

moisture levels, and vegetative health via sensors, cameras, smart phones, and cloud computing to optimize fertilizer and irrigation applications. This data-driven approach helps farmers reduce their overhead costs and enhance overall farm productivity. There are significant benefits of this software for enhancing farm productivity; however, the initial setup cost and learning curve can be challenging.

Smallholder aggregation and processing centers – YieldWise approach to scale up postharvest technologies to reduce PHL in horticultural value chains

Jane Ambuko[15]

Years of research in postharvest science and technology have yielded applicable technologies and innovations to address the challenge of high PHL in food supply chains. However, many of these technologies and innovations have not been adopted for various reasons, including lack of awareness, unavailability, and inadequate knowledge on how to use the technologies. To address some of these hindrances to postharvest technology adoption, smallholder aggregation and processing centers, a technology scale up approach conceptualized by the Rockefeller Foundation's YieldWise Initiative was adopted by the University of Nairobi (UON) Postharvest Research team.

This strategy/approach was introduced on a pilot-scale to two farmer groups in Kenya, namely Karurumo Smallholder Horticultural Farmers in Embu County of Kenya and Masii Horticultural Cooperative Society in Machakos County. The centers are envisioned to be a zero-loss, one-stop center where smallholder farmers aggregate high quality fruits and vegetables for fresh market. In addition, the unsold produce is processed into shelf-stable products (juices and dried products), thereby extending their shelf life and marketing period. The centers have been equipped with simple postharvest technologies including: zero energy brick cooler (ZE-BC) and evaporative charcoal cooler (ECC) for precooling and temporary storage; Coolbot™ cold room for longer term cold storage; small-scale wet processing line; and solar tunnel dryers for dried products.

All technologies at the centers are simple and low-cost postharvest technologies and innovations, which are products of research. Although some of the technologies have been tested and validated on-station (at UON),

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there has been limited commercial application in Kenya. As a result of the pilot centers, there is a positive response from diverse stakeholders who have expressed interest in the technologies. These include county governments in Kenya and private sector actors, including exporters and processors. Through additional support from The Rockefeller Foundation via a grant to Purdue University (Strengthening African Processors to Reduce Food Losses – SAP project), the UON Postharvest Research team will conduct training for mango processors. This will be done in partnership with the Consortium, enabling the project team to expand the training to diverse private and public sector processors.

Conclusion

As stated by Maier (2019), the research agenda for reducing FLAW requires "strong and sustained political will", "suitable policy incentives", and "the power of science and technology". The research agenda of the *Consortium for Innovation in Post-Harvest Loss and Food Waste Reduction* is focused on closing the gap and achieving lasting, systemic change by utilizing the scale-up approach outlined by Cooley and Howard (2019): "(1) design interventions with scale in mind and clear scaling strategies; (2) assess and address obstacles to scalability; and (3) actively manage the pathway to scale".

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Measuring to Manage

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Problem definition and relevance

In a world where more than 700 million people suffer from food insecurity and caloric deficiency, excessive post-harvest loss and food waste (PHL-FW) represents a missed opportunity to use food already present in the production system to reduce hunger, while increasing food quality/safety, nutrition, and market opportunities from small-holder farmers to consumers. Although data on actual PHL-FW are imprecise, the FAO (2011) estimated that approximately one-third of food produced for human consumption – 1.3 billion tons – is wasted or lost per year between farm and table. Subsequent estimates, from numerous sources in diverse settings, have affirmed that the magnitude of PHL-FW is significant (Flanagan et al., 2019). Further, within the 2030 Agenda for Sustainable Development (SDGs), Target 12.3 asserts the need to cut post-harvest loss by 50% by 2030 (United Nations, 2015).

While the magnitude of loss today is concerning, it is even more distressing that excessive post-harvest loss and its associated negative impacts are NOT new topics of global interest. In 1975, then US Secretary of State, Henry Kissinger, made an eloquent plea detailing the need for global efforts to reduce post-harvest loss. Following his exhortation, the UN General Assembly adopted a resolution calling for at least a 50 percent reduction within ten years (Bourne, 1977). However, more than forty years later, we still struggle to find sustainable solutions to mitigate PHL of both cereals and perishables in developing countries.

In recent years, numerous technologies have been identified which can reduce PHL in developing countries (Flanagan et al., 2019). Documentation exists indicating that application of these technologies can reduce PHL and increase farmer profits (Fischler et al., 2011). Even though results of pilot efforts to reduce PHL have a history of positive outcomes, widespread adoption of the associated technologies is the exception rather than the norm (Easterly and Pfutze, 2008; Chandy et al., 2013).

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Hanson et al. (2019) recommend that "countries and companies follow a simple 'Target-Measure-Act' strategy: adopt the Sustainable Development Goal *target* of halving food loss and waste as their own, *measure* their food loss and waste, and *take action* on the hotspots identified". As is often the case, the cost of actually measuring PHL is not rigorously examined. For many sectors in today's economy, digital technologies have reduced dramatically the cost of measurement. However, in agricultural systems based upon smallholder farmers that is not the case and operational measurement can be costly.

In a recent conference statement, the Pontifical Academy of Sciences (2019) stresses that, "while FLAW (food loss and waste) reduction has huge benefits, the costs of action cannot be ignored when aiming for effective and efficient solutions". This reality is particularly relevant with respect to measurement in smallholder farmer systems.

A corollary factor relates to the adequacy of information for decision-making purposes. For academic research, replicable accuracy is essential. While better accuracy is desirable, supply chain managers have to make decisions in a timely fashion. As noted by Bradshaw (2019), "actionable insights are the holy grail of any business' data". Given the sparse nature of available data on post-harvest loss, emphasizing methods that can provide improved insights at very low cost is a worthy goal.

The purpose of this paper is to present an alternative approach to the concept of measurement of post-harvest loss, particularly in systems based upon smallholder farming. The paper's following section will describe the approach. Then a numeric example is provided to illustrate application of the approach.

A more feasible approach to estimating loss

In some parts of food supply chains, measurement systems exist to monitor ongoing operations, for example, within modern food processing plants. In those settings, expanding the focus to include post-harvest losses often is economically feasible. However, on smallholder farms and in those parts of the food chain near the farm, measurement systems tend not to exist. Having to establish appropriate systems markedly increases the cost of physical measurement.

Assessing levels of post-harvest loss is not the only setting where continual, comprehensive measurement is not feasible. For example, estimates of the extent and nature of poverty are important factors affecting policy in developing countries. Continually and comprehensively quantifying pov-

erty across populations would be a time- and resource-intensive undertaking. Attempting to do so would be quite costly.

Because policy makers need to understand the changing nature of poverty, methods have been developed which provide useful and cost-effective means to track poverty. In general terms a three-step process is employed:

1. Careful research is done to identify valid and quantifiable indicators of poverty. For example, an indicator could be the number meals the family consumes in a week.
2. Large-scale, representative, survey research is conducted. Such surveys, for example, could quantify the distribution of families in terms of the number of meals consumed weekly.
3. The sources of information in 1) and 2) are then combined to provide credible estimates of poverty. An important attribute of this approach is that estimates can be enhanced as additional survey information is obtained or as research provides improved poverty indicators.

The general approach just described is applicable as we attempt to understand post-harvest loss and to track the gains from interventions aimed to reduce loss. Again, a three-step approach would:

A. Conduct careful research, relating levels of loss to the alternative post-harvest practices employed. For example, hand-threshing rice is one practice. Use of mechanical threshers and combines are alternative practices. These post-harvest practices are analogous to the poverty indicators noted previously.
B. Large-scale surveys focused on quantifying the practices actually employed by farmers can be conducted to document their extent of use. Because these surveys would focus on what farmers actually do, recall-based responses are likely to be provided with minimal error.
C. As was the case for estimation of poverty levels, the sources of information in A) and B) can then be combined to provide credible estimates of post-harvest loss. To assess the effects of interventions aiming to reduce loss, surveys conducted over time would provide documentation of changes in the level of practices employed and therefore would allow decision makers to track changes in loss.

To this point, the discussion has focused on measurement of physical loss. However, it is important to note that physical losses are only one component of the economic effects of excessive post-harvest loss. Two key economic parameters associated with post-harvest loss are quality levels and the timing of sale of the farmer's product.

The quality of the farmer's output is often highly related to the practices employed on the farm and in transport of the product to market. For example, hand-cut rice is often left for several days to dry in the field. The combined effect of heat in the day and dew overnight can reduce the desirability of the grain, therefore resulting in economic discounts at the market. Research efforts, such as noted in A) above, can assess the relationships between practices and quality to provide data needed to estimate economic losses because of quality deficiencies.

Further, if smallholder farmers don't have the capability to adequately store or condition their output, they often suffer severe economic penalties by having to sell at harvest when market prices are typically at their lowest. This has been called PHL's hidden tax (Sonka, 2014). For staple crops, this penalty is multiplied when the farm family must purchase the same product several months after harvest when prices are high.

Lack of access to appropriate post-harvest practices leads to substantial economic losses from both the effect of reduced quality and inappropriate market timing. In tracking the gains from reducing post-harvest loss, the effects of those parameters must be assessed, as well as the effect of physical losses on agricultural output. The framework described in this note can accommodate both of those factors.

An illustration

The following paragraphs illustrate application of the approach just described for a hypothetical, but realistic, post-harvest loss setting. The context is a rice supply chain from farm production to milling in Bihar state, India.

Figure 1 identifies five columns as relevant stages in the hypothetical supply chain. Three alternative pathways (the rows) are identified. At each node (intersection of supply stage and pathway), a numeric percentage is noted which represents an estimate of typical levels of post-harvest loss.[2]

Three pathways are depicted in Figure 1:

- The topmost pathway is representative of the traditional combination of practices, with hand-harvesting and threshing followed by sun-based drying and storage in jute bags.
- The middle pathway differs from the traditional pathway by employing mechanical devices for harvest, threshing and drying.

[2] To operationalize this illustration, post-harvest loss experts from the International Rice Research Institute graciously provided the estimates shown here. Modeling support was provided by staff of the Centrec Consulting Group, Savoy, Illinois.

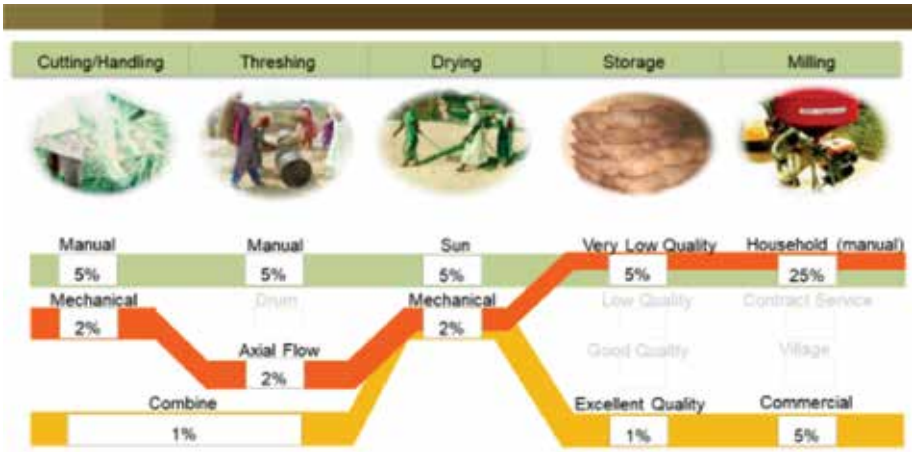

Figure 1. An illustration linking farmer and supply chain practices to levels of post-harvest loss in a hypothetical rice supply chain. Source: Compiled by author.

– The bottommost pathway incorporates combine harvesting,mechanical drying and high-quality storage and milling.
– As noted previously, quality deterioration after harvest is an important economic factor. For purposes of this illustration, it is assumed that systems (pathways), which do little to protect quality, can expect 30% reductions in economic value at the end of the supply chain. Conversely, pathways which strive to maintain quality levels can expect only a 10% reduction in economic value.

The primary benefit of the proposed approach is that the framework is amenable to providing insights for the types of questions smallholder farmers, supply chain managers and policy decision-makers need to address. For example, a policy-maker or a supply chain manager might be interested in having a sense of the economic gains that could be achieved if the dominant system moved from traditional practices to the more modern practices of the bottommost pathway in Figure 1.

To further illustrate that application, let's consider:

– An agricultural district with 10,000 hectares of rice production,
– Rice yields of 2,500 kg/ha in a good weather year,
– An expected market price of 25,000 rupees per metric ton for high quality rice.

Using the parameters noted previously, it's possible to compare the two pathways. Economic estimates resulting from one such comparison in-

clude the following:

- Prior to harvest, the potential economic value for both pathways is 625 million rupees.
- The calculated economic value of the *quantity* losses is:
  243.2 million rupees for the traditional pathway versus
  188.6 million rupees for the improved pathway.
- Further, the calculated economic value losses because of reduced *quality* are:
  114.5 million rupees for the traditional pathway versus
  43.6 million rupees for the improved pathway.
- The resulting gross marketable value[3] estimates are:
  267.3 million rupees for the traditional pathway versus
  125.5 million rupees for the improved pathway.

The numbers and estimates shown here are *not* meant to indicate the relevant value of the various practices mentioned. Rather they are solely meant to illustrate the type of framework and tools that decision-makers could employ to drive actions that can lead to reduced post-harvest loss.

In this illustration, the values linking loss levels to practices were based upon expert opinions. In reality, investigation of relevant research findings and more rigorous assessment of multiple sources likely would be conducted. While decisions generally need to be made at a point in time, decision-making in supply chains typically is a dynamic process. Experience over time can identify key decision points where additional research is critically needed to improve decision-making. Results from that research, combined with operational experience, can lead to better parameter estimates as well as improved decisions.

Concluding remarks

The Target-Measure-Act approach is an attractive means to articulate steps necessary to drive the change needed to reduce post-harvest loss, whether the actors are public or private decision-makers. This paper focuses on the measurement step, noting that acquisition of accurate data within systems based upon smallholder farming is likely to be costly; cost levels which have the potential to exceed expected benefits.

An alternative approach is described and illustrated in this paper. The focus of the approach is production of insights that can enable better de-

[3] The values employed in this illustrative analysis do not include operational costs for the practices. Obviously, actual decision-making would need to consider values that are net of such costs.

cision-making. Further, explicit identification of key practices and their relationship to loss can drive learning through external research and operations.

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Using Crop Diversity to Reduce Food Loss

Stefan Schmitz

Towards a broad approach on feeding the world sustainably

Over the last few decades, science and policy making have significantly changed our view on how to feed the world. This shift towards a broad approach can be summarized as follows:

- Food security is not just a matter of availability of food but comprises four elements: availability, access, utilization and stability over time. This means, in essence, that food security depends not only on the availability of sufficient agricultural production, but also on many other physical, environmental, economic and social factors.
- Food security is not only a question of sufficient caloric supply. In the framework of the so-called Millennium Development Goals (MDG), which covered the timespan from 2000 until 2015, malnutrition was still largely seen as energy undernourishment. The targets under the second goal of the Sustainable Development Goals (SDG 2), which have a time horizon until 2030, now explicitly address all forms of malnutrition, that is, the entire spectrum from caloric-based malnutrition to micronutrient deficiencies also known as "hidden hunger" and the various forms of overnutrition (see for example Ritchie et al. 2018).
- Global food security is at the heart of a very complex system with enormous co-dependencies. This perspective becomes particularly important when we consider not only the food security of people living today, but also the food security of future generations, and as a consequence focus on the sustainability of efforts. Sufficient and healthy food for everybody is linked to productive and diversified agriculture as well as many other factors (see above). Beyond that, agriculture itself is a long-term perspective heavily dependent on factors in the environmental, economic and social spheres.

Against this background of current thinking, the new conceptual framework of "Sustainable Food Systems" has emerged. "Food systems encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry

or fisheries, and parts of the broader economic, societal and natural environments in which they are embedded. The food system is composed of sub-systems, such as the farming system, waste management system, input supply system, etc. and interacts with other key systems such as the energy system, trade system, health system, etc." (FAO 2016).

Food security is and remains one of the central challenges facing humanity in the 21st century. Because of the direct impact, it is first and foremost the Global South that is called upon to act. There are basically two approaches that are suggested. One way leads directly to the industrialization of agriculture as in the Global North, with its agricultural and spatial specialization and its high input of resources. The other way is a more holistic, integrated approach to the management of the agri-food system.

There should be no doubt that many rural regions of the Global South need modernization of agriculture to overcome widespread poverty, hunger and lack of prospects, especially of the younger generation. The current state of agriculture in many regions of the South cannot be called good even from an ecological point of view. Standing still and insisting on the status quo is often not a viable option. Such a modernization would replicate some of the technical, economic and social achievements of the "Green Revolution". But a completely faithful copy of the agricultural model of the North would be a mistake. First of all, the necessary investment capital would not be available in many places. Second, the current industrial agricultural model would not solve many of the problems of the poor rural areas in the South anyway. And third, this model cannot be generalized. Already today it is causing planetary boundaries to be exceeded. Further expansion to a global model would further exacerbate the global crisis of climate, biodiversity and environment.

"Today's food and agricultural systems have succeeded in supplying large volumes of food to global markets. However, high-external input, resource-intensive agricultural systems have caused massive deforestation, water scarcities, biodiversity loss, soil depletion and high levels of greenhouse gas emissions. Despite significant progress in recent times, hunger and extreme poverty persist as critical global challenges. Even where poverty has been reduced, pervasive inequalities remain, hindering poverty eradication" (FAO 2018).

In essence, the concept of sustainable food systems reflects the strong conviction that the challenge of feeding the world in the long term can only be met if more or less all SDGs, from number 1 to number 17, get the same attention and are equally met – in the Global South as well as

in the Global North. Sufficient and healthy diets for all people at all times require, for example, much greater efforts in social service provision (education, health, water and sanitation), in economic development and above all in environmental stewardship, including protection of biodiversity and action on climate.

Agrobiodiversity and crop diversity is important for sustainable food systems

The question is then what ingredients are essential for a serious sustainable food systems strategy. For example, concepts like "low external input agriculture" or, far broader, "agroecology" receive growing attention. This is not the place to go deeper into those concepts. Instead, we will only focus on one specific component here: diversity.

FAO (2018) regards diversification as key to agroecological transitions "to ensure food security and nutrition while conserving, protecting and enhancing natural resources" and puts it number one among the ten elements of agroecology. Agrobiodiversity takes many different forms and includes diversity at both the species as well as the genetic levels, spatial diversity (e.g. through intercropping), temporal diversity (e.g. through crop rotation) and vertical diversity (e.g. through agroforestry systems). Increasing agrobiodiversity contributes to a range of production, socio-economic, nutrition and environmental benefits (FAO 2018).

Diversity within crops is a fundamental component of agrobiodiversity. Diverse seed systems are central to sustainable food systems. "The value of resilient and diverse seed systems goes far beyond any economic measure. Community-based seed systems are connected to diverse cultural and culinary traditions, health and wellness, resilient agroecological landscapes, and sustainable local economies" (Global Alliance for the Future of Food 2016). The conservation and sustainable use of seed diversity is key to ensuring food security, adapting to climate change, reducing environmental degradation, protecting nutritional security, reducing poverty and ensuring sustainable agriculture.

Reducing food loss and waste is important for sustainable food systems

Another important entry point to sustainable food systems is the reduction of food loss and waste. This issue is included in the Sustainable Development Goals: target 12.3 aims to "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" by 2030. A food system

perspective allows a comprehensive investigation into the causes of food loss and waste as a starting point for the development of adequate strategies to address the issue.

There is a common understanding that food loss and food waste occur at different stages of the food value chain. However, no agreement exists regarding further classification of food loss and food waste. The terms 'Post-Harvest Loss', 'Food Loss', 'Food Waste' and 'Food Loss and Waste' are frequently used interchangeably, but they hardly ever refer consistently to the same concept (Delgado et al. 2017). Some recent publications have tried to create more clarity (FAO 2014; HLPE 2014; Lipinski et al. 2013). In these studies, food losses refer to unintentional reductions in food quantity or quality before consumption; these losses usually occur in the early stages of the food value chain, from production to distribution (Delgado et al. 2017). On the other hand, food waste occurs in the later stages of the food value chain too, caused by retailers, food service providers and consumers.

Despite this move towards greater clarity, vagueness around the concepts of food loss and food waste still exists. The major disagreement relates to the question of whether or not loss during the production phase, i.e. between seed planting and harvest, should be included. Delgado et al. (2017) argue very clearly for a further harmonization of concepts and terminology around food loss and waste, and in particular for definition of food loss that includes the pre-harvest phase: "… a standard definition and terminology for food loss and waste is crucially needed. This definition must adopt a value-chain approach, accounting for the fact that conditions at one stage of the chain likely affect loss and waste at later chain stages. Specifically, this definition needs to include pre-harvest loss, as their exclusion could lead to food loss and waste reduction interventions that do not tackle the source of the problem. This new definition must include both quantitative and qualitative reduction criteria, exclude natural, inedible, and unavoidable loss, and be able to be measured in economic, caloric, or quality-adjusted weight terms".

Despite the lack of clarity in terminology and the vagueness of the quantitative and qualitative dimensions of the problem, it is clear that food loss and waste are among the greatest challenges to the sustainability of food systems. According to various FAO sources, of 1.3 billion tons of food produced worldwide for human consumption, about a third is lost or wasted during the various steps of production, harvesting, storage, transport, processing, marketing and consumption. Food loss and waste equal about USD 680 billion in industrialized countries and USD 310 billion in

developing countries. While a high percentage of food is currently lost at production, handling and processing stages in low-income and emerging economies, much food is wasted in the retail and consumption stages in higher income countries due to market design and consumer behavior. In developing countries, 40% of losses occur at post-harvest and processing levels, while in industrialized countries more than 40% of losses happen at retail and consumer levels.

The minimization of food loss and waste will help to relieve pressure on land and reduce the amount of water, energy and other inputs needed for food production. The potential to reduce greenhouse gas emissions is enormous given that current levels of food loss and waste account for about 8% of all man-made GHG emissions.

Crop diversity is a powerful lever to reduce food loss

The conservation and use of agrobiodiversity, especially crop diversity, on the one hand, and the minimization of food loss and waste on the other hand are both regarded as highly relevant for the sustainability of food systems. There is an interesting intersection between these two strategic fields that deserves more attention: the promotion of crop diversity in land use systems can significantly contribute to reducing food loss as one of its many positive effects. And while such crop diversity has a direct effect on reducing loss, it also has further secondary effects: for example, avoiding food loss through crop diversity results in avoided greenhouse gas emissions, increased economic benefits, increased food security and healthy, nutritious diets.

There are many ways in which crop diversity can help to avoid food loss. In some cases, it is sufficient to use the crop diversity available locally. In other cases, breeding using wild relatives and the seed samples conserved in genebanks provides the desired means to reduce food loss. Only a few examples can be given here, which fall into three categories:

- Crop diversity to reduce pre-harvest loss
- Crop diversity to reduce post-harvest loss
- Crop diversity to reduce food loss through levelling harvest peaks and better matching food supply and demand.

Crop diversity to reduce pre-harvest loss

Damage to a crop in the field before harvest is widespread and often important. Production systems that lack diversity are in general more vulnerable to pest and disease outbreaks than those with more diverse pop-

ulations. If a single variety is widely grown, a pest or disease to which it lacks resistance can lead to a dramatic fall in production. If livelihoods are heavily dependent on the crop in question, the effects can be disastrous. This kind of vulnerability has been illustrated in practice on a number of occasions, including the famine caused by potato blight in Ireland in the 1840s, loss in various cereal crops in the United States of America during the twentieth century and loss of taro production in Samoa in the 1990s (FAO 2019).

Plant diseases are responsible for substantial crop loss each year and pose a threat to global food security and agricultural sustainability. Improving crop resistance to pathogens through breeding is an environmentally sound method for managing disease and minimizing these losses (Nelson et al. 2018). The choice of the right variety, adapted to a specific location and meeting the requirements of the market in terms of quality specifications and time of maturity, is an important consideration in the production phase. Incorrect choice of variety leads to products of inferior quality, which in turn leads to high losses. In the case of some cereals, such as maize, wheat and sorghum, the choice of varieties that are particular prone to wind breakage in exposed locations contributes to high losses. An equally important cause of food loss in cereals is the cultivation of varieties that ripen during the rainy season and are predisposed to fungal infection (HLPE 2014).

Diversity matters in this context. Field studies in Uganda, for example, have shown that bean yields have increased significantly when farmers grew three or more bean varieties in the field instead of just one. In Morocco, barley losses caused by powdery mildew could be reduced by using particular traditional barley varieties instead of the usually recommended modern or improved ones (Bioversity 2014).

Crop diversity to reduce post-harvest loss

Pests and diseases also cause post-harvest losses. Breeding again provides opportunities to address this issue. A nice example comes from a cassava wild relative. Dramatically delayed postharvest physiological deterioration (PPD) was found in a wild cassava in Mexico and Texas. A seed sample of this wild relative was crossed extensively to elite cassava varieties. The stored roots of the hybrid remained intact a month after harvest. Backcrosses of this hybrid to elite progenitors of the cassava gene pools were made for genetic mapping of the delayed PPD trait, allowing more rapid screening and breeding (Fregene and Mba 2004).

In many cases, crop diversity leads to a reduction of pre-harvest and post-harvest loss, especially if it is embedded in a broader concept of good agricultural practice. This is, for example, reported for fruits and vegetables, where agronomic practices during the production phase greatly contribute to the product's quality. Pre-harvest pest infestation is known to be a major contributor to post-harvest loss in fruits, as some of the latent infestations only manifest themselves post-harvest. Poor water and nutrient management contributes to poor product quality and leads to a high proportion of rejects. Heavy rainfall favours disease infestation, which can be counteracted with a good mixture of suitable varieties and appropriate cultivation methods. On the other hand, high temperatures cause physiological disorders such as solar yellowing or sunscald, which can also be counteracted with the choice of varieties and cultivation practices. Particularly critical are extreme temperatures in grain cultivation, which can lead to aflatoxin contamination, leading to unsafe food which is therefore discarded.

Crop diversity to reduce food loss through levelling harvest peaks and better matching food supply and demand

Diversity, for example through intercropping or crop rotation or judicious choice of phenologically distinct crops or varieties, allows a staggering of food availability around the year. This leads to reduced need for storage and so less risk of loss. At the same time, avoiding harvest peaks also improves the chance that the crop supply will meet the demand of different target markets and find a buyer; this also means less risk of loss.

Conclusion

The central challenges of humanity in the 21st century are clear: to feed a growing global population sufficiently and healthily; to increase the productivity of millions upon millions of smallholder farmers, improving their incomes and livelihoods; and to establish a global agriculture and food economy that once again respects the limits of the planet. The solution to this major, as yet unsolved, future challenge is now made even more difficult by the changing climate.

There are no simple solutions, let alone a single one. What is needed is a broad approach that enables and promotes a transformation of global food systems towards sustainability. Within such a broad approach, two principles will be of paramount importance. On the one hand there should be "as much agrobiodiversity as possible" and on the other hand there must be "as little food loss as possible". The observance of both principles in-

dependently can achieve a lot. But there is also an interesting intersection between these principles: agrobiodiversity, and in particular crop diversity, can make a considerable contribution to reducing food losses.

The history of farming is above all also a history of continuous generation and management of new diversity. Only in this way has it been possible to ensure survival in the face of constantly changing environmental conditions, the vagaries of consumer preference and the outbreaks of pests and diseases. This need to draw from the pool of diversity to find ever new answers to ever new challenges through breeding is now set to grow significantly as a result of manmade climate change. It is important to be prepared for the unpredictable in this constant process of adaptation. A prerequisite for using diversity in this way is not only its preservation in-situ, in the field, but ex-situ in genebanks. Diversity is a key element in ensuring sustainable production, including through reducing food losses.

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IV: THE NEED FOR SYSTEMIC AND MARKET-BASED APPROACHES AND COLLABORATION

An Innovative Social Enterprise Model Addressing Food Losses in Zimbabwe

Mathias Mogge, Thomas Heyland, Justine Roberts

1. Food losses in Zimbabwe

Zimbabwe has a total land area of over 39 million hectares, of which 33.3 million hectares are used for agricultural purposes.[1] According to FAO, over 70% of the population depends on agriculture for their livelihoods.[2] Zimbabwe is currently experiencing a multifaceted, complex and protracted crisis, characterized by 70% of the population living in poverty,[3] hyperinflation (annual inflation reached 230% in July 2019, compared to 5.4% in September 2018)[4] and widespread, chronic food insecurity, with 59% of the rural population (5.5 million people) food insecure at the peak of the lean season (January-March 2020), of which 3.58 million people will be at crisis or emergency level (Integrated Phase Classification 3 and 4 respectively).[5]

Zimbabwe's current crisis is exacerbated by the effects of climate change, with crop losses associated with both drought and floods. Within this complex environment, in which millions of people live in poverty and at risk of starvation, food loss is a critical concern to ensure that agricultural production achieves maximum potential for food supply and income generation. A study commissioned by the Ministry of Agriculture in 2015 estimated food losses at critical stages of two common value chains, tomatoes and maize. The critical loss points for tomatoes are at the grading and packing stages while those of maize are at the harvest stage and during storage (Figure 1). For maize the study only addressed losses in maize produced for home

[1] FAO in Zimbabwe: Zimbabwe at a Glance http://www.fao.org/zimbabwe/fao-in-zimbabwe/zimbabwe-at-a-glance/en/

[2] Income security for smallholder farmers in Zimbabwe, FAO http://www.fao.org/in-action/income-security-farmers-zimbabwe/en/

[3] World Bank, Zimbabwe Country Profile, Accessed on 22 January 2020, https://databank.worldbank.org/views/reports/reportwidget.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=ZWE

[4] World bank in Zimbabwe: Overview https://www.worldbank.org/en/country/zimbabwe/overview Accessed on 22 January 2020; Page last updated October 13, 2019.

[5] UN OCHA Revised Flash Appeal 2019 http://zw.one.un.org/sites/default/files/ROSEA_revised_Zimbabwe_FlashAppeal.pdf

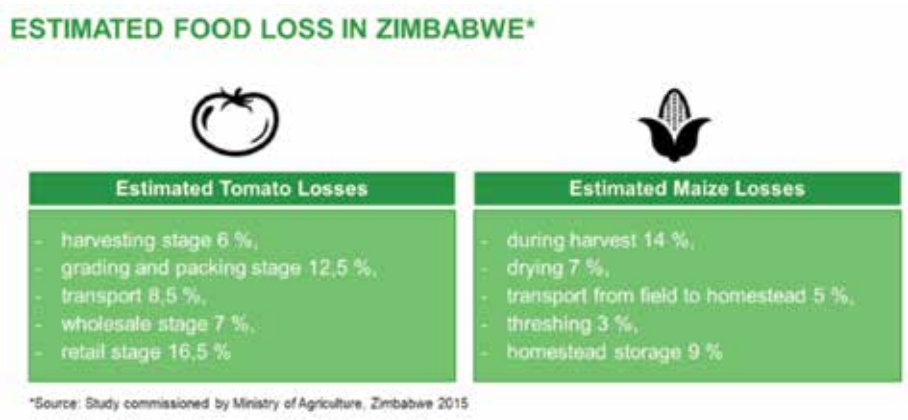

Figure 1. Estimated Food Loss in Zimbabwe. Source: Study commissioned by Ministry of Agriculture, Zimbabwe 2015

consumption, and did not account for the additional losses experienced in storage and transportation during the marketing stage. The African Postharvest Loss Information System estimates that in 2017, the total postharvest loss in Zimbabwe was about 16.4% in maize amounting to 182,720 tonnes valued at US$71,260,800.[6]

This shows that vast potential exists for increasing the supply of food at the national level (and improving farmer incomes) by addressing food losses alone. In this way, increased food availability can be achieved *without the need for increased production, and the associated use of scarce resources* (*land, water, energy, labour, money*) *or agricultural inputs.* In the current context of Zimbabwe's food deficit, reducing post-harvest losses for maize would also reduce the need for using limited foreign currency reserves for importing grain.

2. The evolution of the Agricultural Business Centre (ABC) model

Welthungerhilfe (WHH)[7] emerged from the *Freedom From Hunger* Campaign of the United Nations Food and Agricultural Organization (FAO) in 1962. WHH is one of the largest non-religious, private development NGOs in Germany, with 30 country offices in Africa and Asia. Supported development projects in its partner countries are focused on food security, which includes all the activities along the value chain from the field to the consumer, in order to improve quantity and quality of available

[6] African Postharvest Losses Information System (APHLIS) aphlis.net
[7] Welthungerhilfe https://www.welthungerhilfe.org/

food. WHH has been working in Zimbabwe since 1980 with an annual turnover of €2.7 Mio, reaching 786,000 people (2018).

WHH-Zimbabwe takes a market-oriented approach to agricultural development, recognising that successful agricultural production is hinged on viable sustainable markets for the end products. However, WHH's experience of linking farmers and farmer groups directly to commercial buyers has shown that breakdowns in these relationships can easily occur, requiring third party intervention to resume effective communications and relationships between the private sector and the farmers. In general, agribusiness companies and financial institutions find dealing with individual smallholder farmers too risky, time consuming and expensive, whilst private companies often neglect minimum environmental and social standards. In some instances, farmers deal with unscrupulous 'middle men' who prey on farmers' desperation when they need to sell crops and might be willing to accept lower than market prices (and even lower than cost price) just to raise cash to meet immediate needs. In other cases, farmers that engage in contract farming agreements will side-market to external companies for a slightly higher price, but in doing so jeopardise the future of any further private sector investment. At the same time efforts to formalize farmer organizations as cooperative and community-based enterprises are often not sustainable once external project funding has ended.

With funding from the European Union, WHH, in partnership with a business development organisation, Empretec,[8] established the Agricultural Business Centre (ABC) as a means of formalising and commercialising the market intermediary role that is usually played by NGOs. The ABC is constituted as a private limited company, to be a commercially viable entity that provides various intermediary services to local farmers, such as identifying and brokering viable market opportunities, bulking, processing, transporting and value addition for output markets and procuring and retailing inputs and services for high quality market-oriented production. Located in Gokwe South, the second largest district in Zimbabwe, the ABC concept and structure emerged from WHH's ten years of engagement with smallholder farmers in the district.

The ABC is a 'social' enterprise, meaning that it takes a private sector, cost-efficient, profit-making approach to delivering services that achieve social goals. In this instance, the ABC as a private sector entity is an inno-

[8] Empretec Zimbabwe: http://www.empretec.co.zw/index.php?option=com_content&view=article&id=61&Itemid=62

vative solution for the long-term sustainability of in-demand services that benefit family farmers. As a social entity the ABC looks beyond the profit motive to ensure that the opportunities created by the business are inclusive and sustainable. At the same time, its private sector service delivery is focussed on identifying and satisfying market needs, ensuring cost-effectiveness and reliability in order to maintain commercial contracts. Unlike 'projects', the ABC's services are not time-bound and are forward-looking by nature, anticipating and adapting to changing circumstances. The concept of the ABC as a private sector entity replacing the intermediary role of NGOs for facilitating value chain output and input markets is a disruptive innovation in the sphere of rural development. It is premised on the notion that continued support is both necessary and desirable for maintaining functional relationships between commercial agro-businesses and smallholder farmers.

The Agricultural Business Centre (ABC)

The ABC is commercial enterprise, registered as a limited company, and operates as an inclusive social enterprise, delivering needed services for farmers and consumers on an ethical pricing basis, however, with a for-profit motivation.

Acting through a dedicated intermediary service that understands both the commercial needs of the market and the practical needs of smallholder farmers reduces risks and enhances the benefits for both parties.

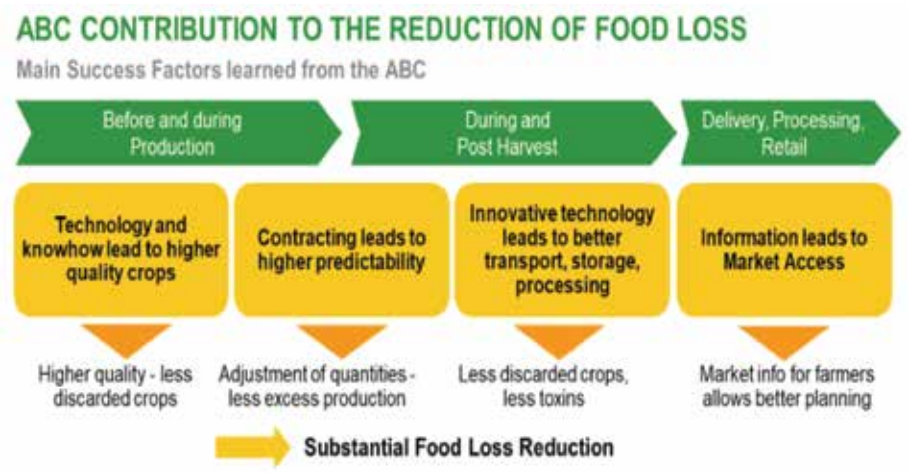

Figure 2. Source: compiled by author.

The ABC is constituted in a manner that adheres to the FAO's ten Principles for Responsible Investment in Agriculture and Food Systems by ensuring that investments made prioritise, strengthen and secure the needs and priorities of smallholders.[9] These principles reinforce the ABC's commitment, as an inclusive social enterprise, to balancing sustainable economic development with maintaining a focus on food security.

Figure 2 illustrates the various points along the value chain at which the ABC plays a critical role in reducing food loss, supporting farmers for improved efficiency at production and post-harvest stages, and facilitating efficient storage and delivery to predetermined markets. The next section explains in more detail the specific roles and services provided by the ABC as a market intermediary connecting smallholder farmers to markets.

3. The ABC market intermediary role

The ABC acts as a strategic market intermediary, receiving high quality produce from the local farmers. The ABC is able to pay farmers a price for their produce that in most instances is above the previous market norm. The ABC invests in appropriate technologies for on-site storage, processing and packaging, thus adding value to achieve a higher market value for the produce. As an intermediary, the ABC acts as both buyer for output markets and as a service provider for farmers. During its first year of operation the ABC in Gokwe has developed and tested four business models:

Model 1: Staple crop (Maize)

In its first year of operation (2018) the ABC helped smallholder maize producers to sell and deliver their maize to the Grain Marketing Board (GMB), the parastatal entity responsible for grain procurement and distribution. Based on market analysis the ABC identified that GMB offered the best price for that season, and provided an aggregating and delivery service for farmers.

The ABC also provided capacity building to local farmers to ensure that they were aware of the GMB's minimum requirements (quality, moisture content and others). This was done as a joint effort with GMB staff, including procurement of grain moisture test meters so that farmer groups were able to check the moisture levels ahead of delivery to GMB (or other

[9] Principles for Responsible Investment in Agriculture and Food Systems, Committee on World Food Security http://www.fao.org/3/a-au866e.pdf

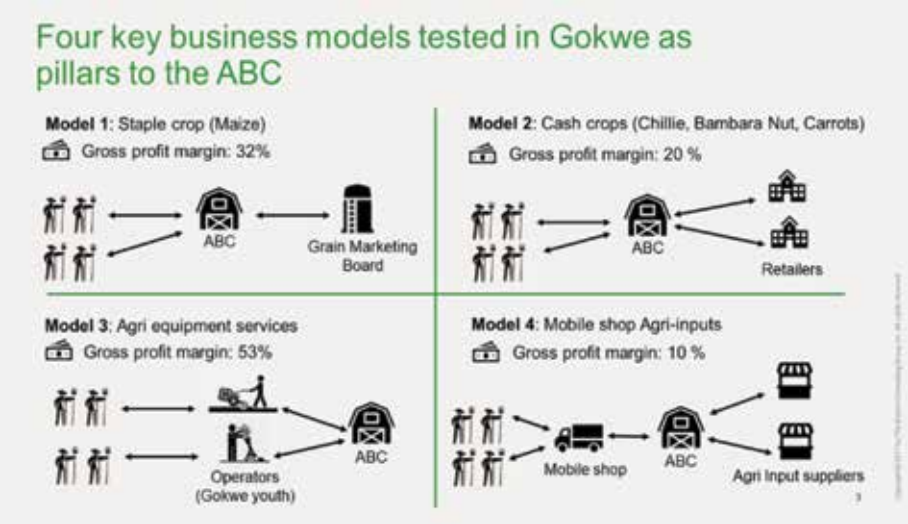

Figure 3. Source: compiled by author.

markets in the future), reducing losses when grain that does not meet the standards is rejected.

Maize was bought from the farmers at a premium price of US$4 per 20l bucket, which translates into US$240 per ton, compared to US$ 180-200 that the traditional middlemen were paying at that time, hence the farmers received 20% more income from selling their product through the ABC. The GMB price was fixed at US$390 per ton. In total, 218 tons of maize was procured for a value of US$52,423. Payments received from GMB amounted to US$86,359. Taking into account costs of delivery (US$3,653 for labour and transport) the ABC was able to realize a surplus of US$30,283.

Model 2: Contract farming (horticulture)

In this model, the ABC secures a private sector buyer and then sub-contracts local farmers for production. Farmers are able to access more lucrative markets than they could as individuals, whilst the ABC is able to realize a surplus, after paying farmers and meeting costs, from bulking and delivering high quality produce. The ABC as contractor provides inputs, technical support and guidance to farmers to ensure high quality production. However, unlike traditional commercial farming arrangements, the ABC also acts in the interest of the farmers when negotiating with the

private sector buyer, and ensures that it is able to buy from the farmers at the best possible price. For example, for a Nyimo bean (a pulse, also known as Bambara nut) contract the ABC offers the following services to farmers to ensure high quality production:

1. Procurement of seed for selected varieties that will have to be grown by the farmers. Each farmer receives the seed for free up front, but the amount received is then deducted from the produce at point of sale. For example, if a farmer receives 5kg of seed, 5kg will be deducted from the harvest delivered to the ABC and the farmer will get paid for the balance at prevailing market prices. This reduces losses associated with use of sub-standard inputs.

2. Farmer assessments by ABC trainers with the help of Ministry of Agriculture extension officers and selected lead farmers to establish if the farmers have the land and required labour, as well as successful production history. Thus, only farmers with demonstrated capacity were contracted for Nyimo production, reducing losses from speculative planting from farmers who do not have capacity

3. Farmer technical training for high quality Nyimo production. This involved local extension services, business and group dynamics training. Extensive monitoring visits supported the trainings, ensuring optimal crop management throughout the growing cycle, including timely and appropriate pest and disease management, reducing losses during the production stage.

4. Bulking and grading of the produce and a guaranteed market, minimising losses of speculative production result in market surplus, and of inefficient transporting of small loads.

In this way smallholder farmers are linked to commercial buyers, with ongoing technical support from the ABC, which also then manages the relationships with the buyers ensuring on-time delivery of the required quality and quantities.

Model 3: Agri-equipment and services

The ABC provides a number of technical services to local farmers. For example, the ABC developed a Shelling Services Business as part of the value chain enhancing services to help address losses – as well as labour, time and cost challenges – faced by sorghum and maize farmers. The maize/sorghum sheller has a cost-saving advantage of up to 30% when compared with the traditional methods used by farmers. Farmers can also access and share agricultural equipment using AgriShare, WHH's mobile phone-ena-

bled platform that links farmers without assets with commercial or private hiring services for production, processing and transporting.[10]

The ABC has also invested in constructing solar dryers, which are used for drying vegetables and mangoes, both of which generate added-value for on-selling (attracting up to a 500% premium on fresh fruit for mangos) as well as preserving fresh produce which may otherwise go to waste.

Model 4: Agri-inputs supply (last mile distribution)

The ABC secures low prices for bulk purchase of inputs and passes this saving on to member farmers. Currently, this service is being offered as an incentive to local farmers, who are able to purchase inputs from the ABC at cost price. This allows local farmers to secure high-quality inputs from a local supplier, reducing costs and/or time for farmers to access inputs. In 2019 the ABC also piloted a model for taking inputs directly to farmers, reducing the need to travel to the district capital business center, using a 'mobile shop' model, which applied a modest 10% margin to cover the additional costs, but still delivering at an improved price for farmers who benefit from the ABC's economies of scale for bulk purchasing and reduced transport costs for reaching input suppliers. Further economies are achieved by farmers' aggregating their input needs through existing informal and formal financing groups such as Rotating Saving and Credit Associations (ROSCAs) or Savings and Credit Cooperatives (SACCOs). This helps to ensure that farmers have access to high quality inputs at the correct time, reducing losses from poor quality seeds and late planting.

4. Role of the ABC in reducing food loss

At the farmer level, the ABC supports improved production, focusing on efficiency and cost effectiveness. The ABC is motivated to ensure that the farmer herself or himself will maximise their income potential, as well as applying an overarching lens of environmental sustainability and climate adaptability. Thus, agricultural extension support is focused on ensuring that farmers can gain the maximum potential from the most efficient use of inputs, in a manner that is socially, environmentally and financially sustainable, as well as commercially viable. The ABC works with government agricultural extension agents to provide technical support and guidance

[10] https://www.welthungerhilfe.org/agrishare/

for the diverse range of crops grown by local farmers, which includes direct technical support to contracted farmers (as per Model 2 above) to ensure that minimum standards for the market are achieved. This includes a specific focus on pest and disease management, harvest and post-harvest handling, all of which contribute to minimising food loss and maximising the efficient utilisation of resources. In line with the social mandate of the ABC, integrated pest management is prioritized over the use of agrochemicals, and efficient water use is promoted for irrigation. Thus, capacitated farmers are able to increase their final production without increasing their landholding or use of resources. In addition to the specific technical support for contracted crops, farmers are also able to access production guides and market information using WHH's *Kurima Mari* mobile phone app.[11]

Importantly, as a social enterprise that works closely with the community, the ABC also promotes 'Family Farming as a Business' (FFAB) through the partnership with Empretec. Farmers working with the ABC are encouraged and supported to view their farming as a business activity. This enables the farmer to quantify the cost of crop losses and appreciate the gains achieved through improved production and harvesting techniques, as well as minimising the use of expensive inputs as much as possible. Similarly, the ABC promotes planned planting, ensuring that planting windows are designed to maximise access to markets, reducing the risk of a glut harvest with no market, resulting in loss of fresh produce. This combined approach allows farmers to see the impact of improved production and motivates farmers to reduce loss at all stages from planting through to harvest.

The ABC plays a vital role in securing markets for its member farmers. The ABC manages the market relationships and negotiations and ensures that production quality, quantity and timing are all assured to meet the needs of the market. Efficient and timely transportation and delivery ensures that produce reaches the market in optimal condition, further minimizing losses. Currently the ABC is supplying centralized markets in Harare, but in future will proactively pursue packaging, branding and marketing for local markets, reducing the time and distance to reach markets and ensuring that produce reaches end users at peak freshness, reducing food losses experienced at the consumer level. By investing in packaging and branding, the ABC is motivated to ensure that its brand is associated with high quality and lasting freshness of its produce.

[11] https://play.google.com/store/apps/details?id=zw.co.kurimamari&hl=en

Impact on food loss at different stages of the value chain

Before and during production:

- Providing access to proper inputs at the correct time (reduced losses associated with sub-standard inputs and wrong planting dates)
- Improved technical and extension support to farmers, including proper use of pesticides and integrated pest management (reduced losses from poor crop management, pests and diseases, and post-harvest handling; reduced losses from rejection based on the quality requirements of the market)
- Contract farming offering a calculable market (reduced losses from speculative planting resulting in production surplus to market demand)

Post-harvest handling and storage:

- Improved focus on food safety (reducing losses due to pesticide and fungal contamination)
- Improved storage and handling, including promoting higher quality storage bags for on-farm storage (reducing losses due to molding, rotting and rodents)

Market delivery and processing:

- Improved local markets and bulking facilities (reduced loss from extensive transportation to distant buyers and processors)
- Improved local processing and preservation facilities (reducing losses associated with inefficient manual shelling, or from glut harvests or market surpluses)

5. Sustainability

The hypothesis of the ABC model is that institutional sustainability will be achieved through meeting a clear gap in the market for provision of value chain intermediary services between smallholders and the private sector. By establishing a private sector entity, the ABC will be flexible, opportunistic and dynamic in responding to changing market conditions and arising opportunities. As a founding board member WHH takes the lead in ensuring that a commitment to promoting sustainable agricultural production is entrenched within the ABC's mission as well as the social commitment to improve the living conditions of smallholder farmers, which will

form an important component of the ABC's business plan. Meanwhile in commercial platforms the ABC will promote and exploit the commitment to sustainable production as a unique selling point for the business.

The founding members of the ABC comprise the two NGO shareholders, WHH and Empretec. However, the growth vision for the ABC is to bring on board both private sector actors and farmers. Private sector shareholders and investors will ensure that the ABC remains commercially focused and viable, whilst the development agencies ensure that the ABC remains socially and environmentally accountable.

6. Challenges to the model

Zimbabwe currently ranks 140 out of 190 countries in the Ease of Doing Business Index,[12] and the Zimbabwean operating environment presents a myriad of challenges to establishing and maintaining a viable business enterprise. For example, during its first year of operation, it took five months for the ABC to secure all of the documentation needed to open a commercial bank account. Business registration processes are all highly centralized, necessitating trips to the capital to complete each stage. Even once a bank account is secured, hyperinflation and lack of cash liquidity in the economy present ongoing challenges to all businesses. A further challenge is the unstable regulatory environment around agriculture. For example, in 2018 maize bulking was a win-win activity for farmers and the ABC; in 2019 the government reinstated its monopoly as sole purchaser of maize in Zimbabwe (at prices that are not commercially viable), thus depriving both farmers and the ABC of a profitable income stream.

7. Future plans and potential

The ABC model is designed to be self-sustaining through its commercial activities, hence it will also continue to seek out and access public start-up capital as well as private investors. As such, in the coming year the ABC intends to expand its services and further diversify the supported value chains. Planned services include an increased focus on localized value addition, including drying, packing and/or branding for local markets (reducing losses from transportation and storage). Crop diversification will be promoted, targeting e.g. sunflower production, which is a more drought-tolerant dry-land crop than maize. The ABC will buy the sunflower seed and invest in an oil press for oil processing. Whilst some sun-

[12] The World Bank: Doing Business https://www.doingbusiness.org/en/rankings

flower is already produced in the district, currently no pressing capacity exists locally. Thus, local processing can help to reduce losses associated with bulk transporting, whilst the ABC will also produce seed cake for stock feed from the usually discarded residues for on-selling to local livestock farmers as an additional income stream. The ABC will also be expanding contracted chili production in response to identified market opportunities for supplying chili processors (including potential for export). The ABC will also research viable opportunities for further expanding its service provision and market intermediary role for relevant livestock markets. For farmers the ABC intends to pursue options for linking ABC customer cards to a local bank to improve the efficiency of payments, and will also look at ways for increasing the use of targeted ICT solutions for more effective and efficient extension delivery.

Early activities of the ABC have shown that it can provide in-demand services for farmers, paying a fair price for fresh produce and then adding-value for on-selling and achieving a surplus after covering costs. In the longer term the surpluses can be reinvested into additional services and equipment to grow the portfolio offered by the ABC, ultimately moving it towards financial self-reliance.

Reducing Food Losses in Developing Countries: Simple Technological Solutions, Complex Adoption Along Supply Chains[1]

Rob Vos

1. Introduction

Population growth, rising incomes (which lead to changes in dietary patterns), and limited availability of land and other natural resources endanger global food security. These challenges are particularly acute in developing countries and pose considerable risks to poor populations. A promising strategy to mitigate these problems is to reduce losses and waste from food production to human consumption: across the food value chain, there are considerable losses of agricultural production that could have fed vulnerable populations. The United Nations has recognized the importance of this approach in the Sustainable Development Goal Target 12.3, aiming to "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" by 2030.

Much recent attention has focused on the measurement of food losses (including post-harvest losses), which remains challenging. Many still quote an early global estimate of FAO (2011), which suggests that as much as one third of all food production gets lost or wasted before human consumption. More recent, but incomplete, estimates suggest losses could be considerably less than previously thought, albeit still significant, especially when also accounting for losses in food quality (Delgado et al. 2017; FAO 2019), Likewise, too little is known about which factors are associated with food loss and waste, especially in developing countries. Inadequate post-harvest handling practices and lack of cold or dry storage and transportation are among several known food chain weaknesses that are major causes of food losses. Yet, even where farmers and other supply chain ac-

[1] This paper is based on the author's presentation at the Pontifical Academy of Sciences (PAS) Conference on Reduction of Food Loss and Waste (Vatican, Casina Pio IV, 11-12 November 2019).

tors are aware of the economic benefits (net of costs) of proper storage and handling practices, we do not always see widespread adoption of such practices. This maybe the case, for instance, if farmers perceive greater payoff from investing in increased production or do not have enough market access to reap the benefits of food loss reduction. Overlooking such economic drivers could lead to ineffective intervention strategies. This paper explores the implications for policy design and investment strategies for the development of more efficient food systems in developing countries.

2. What do we know about food loss?

The SDGs include the target of halving food loss and waste by 2030, but from what level? We know remarkably little about the extent of food loss and waste. In 2011 an FAO report came out stating that probably one third of all food produced either gets "lost" during production, distribution, or processing, or "wasted" during retailing and household consumption (FAO, 2011). Though everybody still cites this staggering number, it is based on rather thin evidence. A more recent FAO study now estimates global food losses (up to the retail stage) at 14 percent on average worldwide, but – for lack of reliable data – does not give an estimate for global food waste (FAO 2019). IFPRI research (Delgado et al. 2017, 2019), which influenced the latest FAO study, focuses on *food loss* during the first stages of the supply chain (farming, transportation, storage, wholesale distribution, and processing). Though applied to a limited number of staple crops and country cases, three key findings stand out from that research.

First, it confirms that food losses can be substantial in developing countries, ranging from between about 6% and 26% of the produced value of staple crops (see Figure 1). That estimate includes losses both in terms of quantity and quality. Quality losses may refer to less nutrient content, caused for instance by poor handling of crops on the field, and visibly poor aspect of food items, caused for instance by excessive exposure to heat or humidity during storage, transportation or selling in the marketplace, which in turn may imply products are sold at a lower price, thus constituting a loss in economic value for farmers or traders.

Second, when properly measured, such quality losses tend to be greater than quantity losses (Figure 1). This is an important finding. It means that not all food loss defined this way goes unused; rather much may be used for animal feed or is still consumed by people, though it presents less economic value to farmers and consumers have less nutrient intake and, possibly, are exposed to increased food safety risk.

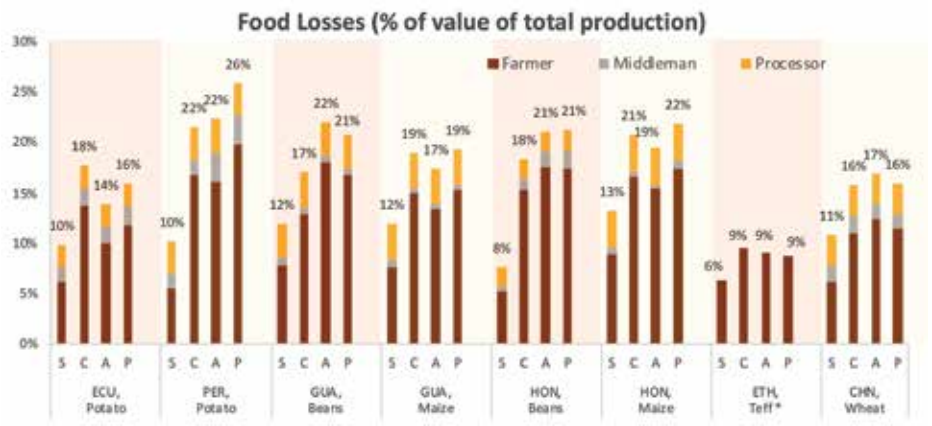

Figure 1. Food losses along value chains in selected developing countries, data around 2016 (% of the value of total production). Note: ECU = Ecuador; PER = Peru; GUA = Guatemala; HON = Honduras; ETH = Ethiopia; and CHN = China.
S, C, A, and P refer to different measurement methods as further specified in Delgado et al. (2017), whereby the first (S-method) refers to self-reported quantity losses by farmers, middlemen and processors, while C, A, and P try to capture both quantity and quality losses through different estimation methods. Specifically:
S = Refers to food loss as measured by the 'aggregate self-reported method', that is based on reporting by the producers, middlemen, and processors regarding the food losses they each incurred.
C = The 'category method' is based on the evaluation of a crop and the classification of that crop into quality categories. Each category is associated with a crop damage coefficient, indicating the percentage of the crop that is damaged within each category.
A = The 'attribute method' (A-method) is based on the evaluation of a crop according to inferior visual, tactile, and olfactory product characteristics. The producer and the middlemen declare how much their respective buyers punish them for inferior product attributes by paying a lower price. The price punishment information for each product attribute is used to estimate the value loss.
P= The 'price method' (P-method) is based on the reasoning that higher (lower) values of a commodity reflect higher (lower) quality.
Source: Delgado, Torero and Schuster (2017, 2019).

The third main finding from IFPRI's research is that, in developing countries, most of the losses of staple crop production (roughly between 55% and 85%) occur at the farm level, while the average loss at the middleman and processor levels lies around 7% and 19%, respectively. The causes, however, lie to a large extent beyond the farmgate.

3. What causes food loss?

Why do food losses occur? There is no simple answer here, as the reasons are multiple and vary greatly from context to context. In developing countries, much food gets lost because of poor handling on the farm, as

well as rodents and fungi that damage crops in the post-harvest process.[2] But economic reasons often are also a cause. Here I will focus on these economic drivers, as these seem most critical for several reasons.

First, low market prices may cause farmers not to market all of their produce or not harvest everything, because it does not pay off. This may be the case, for instance, if the cost of seasonal labor for the harvest and post-harvest handling is too high relative to the farmgate output price. In Ecuador and Peru, for example, about half of potato farmers report that low prices and/or the high cost of labor are the cause why they leave produce on the field (Delgado et al. 2017).

Second, Goldsmith et al. (2015) provide evidence on how poor market incentives lead producers of soybeans and maize in tropical Brazil to accept significant post-harvest food losses in the intercropping season. In this case, farmers producing both soybeans and maize cannot afford any delay in harvesting soybeans so as not to miss out on the timely plantation of the more profitable second crop (maize) on the same land, as delay in planting would expose maize cultivation to higher risk of losses. As the opportunity cost of delayed plantation of the second, more valuable crop is higher, it may lead farmers to hasty and improper harvesting and handling of soybeans, especially if the cost of hired seasonal farm labor is high relative to the crop's output price, and, hence, lead to greater post-harvest losses of soybeans.

Third, farmers and other supply chain actors may perceive that the expected benefits of adopting improved harvest and post-harvest handling practices that reduce food losses are not big enough be it relative to the cost of introducing such practices or to the expected returns of investing in inputs to increase output. A study by Chegere (2018) shows that maize farmers in Tanzania make rational economic decisions regarding whether or not to adopt better post-harvest handling practices and storage capacity. While certain practices (like timely harvesting, maize sorting and disinfecting storage facilities) have been shown to pay off economically, their adoption has remained low among Tanzanian corn farmers. Some farmers expect the gains will be too small compared with the expected gains from alternative investments that would lead to higher production, while others appear to stick to existing practices as a risk-averse strategy, being unable to foresee the economic gains. Sheahan and Barrett (2017) draw similar conclusions from a survey of evidence on post-harvest loss interventions in

[2] See Nakasone et al. (2020) and Sheahan and Barrett (2017) for reviews of evidence for determinants of food losses in low-income countries (mostly in Africa).

Africa. While several studies found favorable benefit-cost ratios for better on-farm post-harvest handling practices, particularly use of hermetic plastic bags, farmers may be incapable of internalizing the expected returns, explaining low uptake. Likewise, Nakasone et al. (2020) find that post-harvest losses tend to be higher among maize-producing farmers with larger production capacity in Malawi, Nigeria and Tanzania. They see as evidence confirming that farmers expect higher gains from investing in output increases than efforts to minimize post-harvest losses.

Fourth, the same studies also conclude that food losses diminish significantly where farmers have better access to markets (e.g. being closer to roads) and where there is capacity to store and process agricultural produce. Those conditions are more favorable the better integrated the food supply chain. Conversely, losses are larger when there is no proper development of cold- or dry-chain storage, transportation infrastructure and food processing capacity. As food chains develop, one also sees farmers engaging in better handling practices, seeking better storage and being required to undertake better quality control and package or protect produce when taking it to market. Also, where costs of transportation and distribution are lower, one observes fewer pre- and post-harvest losses (see e.g. Rosegrant et al. 2015).

4. What can be done about it?

Understanding the causes also provides the basis for finding the solutions. There are simple and often low-cost technological solutions. For instance, research at IFPRI showed that through quality-based contractual arrangements, loss of quantity and quality of beans production in Guatemala dropped by almost 10%. Similar impacts are found when introducing the use of hermetically sealed bags for maize in Ethiopia, and even much bigger impacts of use of solar-powered cold storage for fruits and vegetables as implemented by Coldhubs,[3] a social enterprise in Nigeria.

While there can be *simple solutions,* getting them to work for food markets at large is more complex. Isolated interventions may not suffice, and farmers and other food system actors may not adopt better practices if they do not see enough profitability in investing in better, loss-reducing practices, as pointed out by several studies (see e.g., Nakasone et al. 2020, Sheahan and Barrett 2017, and Chegere 2018).

Furthermore, other assessments indicate that the introduction of better practices require adjustments throughout the supply chain for these to be

[3] See http://www.coldhubs.com

effective and profitable to all food system actors involved. Bradford et al. (2018), for instance, conclude that the adoption of "dry chain" systems[4] in developing countries requires multiple changes in food supply chains to encourage its broad adoption and ensure effective food loss reduction while preserving food safety. This can be explained as follows. Smallholder farmers currently often have limited access to drying and storage facilities, so their choices are to sell their products to traders immediately after harvest or to store them for own consumption or later sale but at high risk of spoilage. While they would benefit from drying, there are disincentives for farmers to invest in commodity drying. If sold by volume, low moisture content is not rewarded, and if sold by weight, the farmer loses money on every kilogram of water that is removed. The availability of humidity meters or indicator strips, or other means to test or guarantee dryness (e.g. through certification) could enable price compensation according to product dryness even in rural markets and incentivize on-farm drying.

Similar requirements for changes throughout the supply chain were found with the implementation of the Purdue Improved Crop Storage (PICS) program supported by the Bill and Melinda Gates Foundation.[5] The PICS program is based on farmers purchasing hermetic storage bags and reusing them for several years to recoup their initial investment (Baributsa et al. 2014). The harvested crops are stored on-farm in the PICS bags and marketed in bulk with the farmer retaining the bags for reuse. A problem with this practice is that it makes the product susceptible to rehydration and pests downstream in the marketing chain when left in open storage (e.g. keeping the bags open when selling in the marketplace), thus requiring behavior change by vendors. Alternatively, in a recycling system, the bags could be collected at the processing plant or end-use sales point (say, near urban areas or transport centers) and returned to farmers for reuse. This would create additional entrepreneurial opportunities for providing mobile drying services, bags and containers in agricultural areas and recycling containers back to farmers. Another option would be to turn traders or end users (e.g., millers and food processors) in the value chain into owners of the bags or contain-

[4] "Dry chain" is referred to as the process of initial dehydration of typically non-perishable food products like grains to levels preventing fungal growth followed by storage in moisture-proof containers. This is analogous to the "cold chain" in which continuous refrigeration is used to preserve quality in the fresh produce industry. However, in the case of the dry chain, no further equipment or energy input is required to maintain product quality after initial drying as long as the integrity of the storage container is preserved.

[5] See https://www.purdue.edu/postharvest/purdue-improved-crop-storage-pics/

ers, who would provide them to contracted farmers and recycle them, with costs recouped from the reduced losses and higher product quality obtained.

Adjustments will also be required at the processing stage. Food processors often reject high percentages of purchased commodities due to quality standards and, where applicable, mycotoxin contamination, like aflatoxin (as often found in improperly handled maize or groundnuts). The financial costs of these losses could be avoided through investments in drying services or providing packaging for free or at low cost to farmers. The latter model has been successfully implemented by some seed companies in Bangladesh, where the companies provide containers and drying beads to their contracted seed producers to efficiently dry their seeds. Containers and beads are returned to the company for reuse along with the higher quality dried seeds (Van Asbrouck and Kunusoth, 2015).

These examples show that for food loss prevention measures to work it is critical that the solutions:

- Provide enough incentive to farmers to reduce food losses and improve food safety (e.g. through *quality certification* and a price premium on better quality products)
- Are cost effective (for farmer as well as other value chain actors and consumers)
- Work across value chains and leverage private initiative to provide temperature-controlled storage and transport, and adequate handling in wholesale, processing, and retail
- Are considerate of trade-offs with food access (*not raising prices disproportionately*)
- Are consistent with food safety standards.

These pre-conditions suggest that reducing food loss should be part of interventions that improve the functioning of the food value chains at large. The consequent recommendation is that *interventions for the reduction and prevention of food loss should be part of broader food and agricultural policies in support of the development and integration of food systems, rather than specifically targeting food loss mitigation*.

In principle, everybody stands to gain if we can reduce the loss of food quantity and quality. It would make food systems more efficient, making the cost of food go down and increasing the nutritional value of food. That will be a gain for consumers, but it may also be a gain for farmers because they can sell more and produce at lower cost. There can be environmental gains if it means less resources get wasted and there is less pressure on the environment. However, it would be way too simplistic to state that it will solve problems of world hunger, climate change and environmental degradation. For farmers to

really gain they will need to see the development of the full value chain. The cost of cold- and dry-chain development, better packaging, and so on can be significant. If only applied to a part of the market food cost per unit will be high and confront consumers with higher food prices, which will limit food access for poor people. There may be no environmental gains if less food gets lost but the same amounts still get produced to meet higher food demand. All of this is to reiterate that one needs a food systemwide approach to tackle the problem of food loss and waste in order to obtain the desired societal gains.

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Eliminating Food Waste: A Country Diagnostics Perspective

Geeta Sethi, Lucia P. Avila Bedregal, Simmy Martin, Rafael Flor

Introduction

A system ripe for transformation

Transformation of food systems is needed at a global scale to foster healthy people and a healthy planet. One of the greatest challenges humanity faces is that of feeding its growing population – projected to reach 9.7 billion people in 2050 – under a changing climate, while remaining within "planetary boundaries" and meeting the Sustainable Development Goals. Until now, food production has outpaced population growth, but it has done so at great environmental cost. Environmental destabilization, moreover, is making it ever harder for food systems to deliver, and to do so sustainably. Climate change and resources degradation threaten to further slow already decelerating agricultural yield growth, beckoning farmers to resort to environmentally harsher practices. They are also increasing the vulnerability of the roughly 500 million family farms responsible for about half the world's food supply (Graeub et al. 2016). Meanwhile, despite food systems' impressive capacity to feed the world to date and a long-term decline in undernutrition, hunger has been rising since 2015 and more than 820 million people had insufficient food in 2018 (SOFI 2019).

Overall, at least 2 billion people were food insecure, many of them struck by the "hidden hunger" of micronutrient deficiencies (SOFI 2019). What is more, over one in two people globally may be experiencing various forms of diet-related disease – now the leading cause of death globally (GBD 2017 Diet Collaborators 2019)[1] – as a result of consuming low-quality diets that are nutritionally unbalanced, characterized by nutritional excesses as well as deficiencies. Considering these and other challenges, a wide range of scientists and policy makers are coalescing around the view that major shifts in global food systems are needed to make them more compatible with a changing climate and societal aspirations.

[1] Poor diets were responsible for 10.9 million deaths, or 22% of all adult deaths in 2017; they also resulted in 255 million disability-adjusted life years (DALYs). Cardiovascular disease was the leading cause, followed by cancers and diabetes.

Food loss and waste: commonly overlooked but with unprecedented potential

Among the host of immediate actions that could help make food systems more climate-friendly and sustainable, reducing the volume of food that is lost or wasted is gaining attention as a significant yet largely overlooked candidate. Food loss typically refers to the discarding of food upstream in the food supply chain, from the farm to wholesale stages. Food waste typically refers to the discarding of food further downstream in the supply chain, at the retail and consumer levels. In either case, food is discarded for various reasons, ranging from spoilage – actual or perceived – to real or suspected changes in food's quality, such as its appearance, flavor, texture, nutritional value, or safety.

The magnitude of food loss and waste (FLAW) is undeniable. In 2015 the world lost or wasted an estimated 1.6 billion tons of food – nearly one-third[2] of what it produced – and that amount was projected to reach 2.1 billion tons by 2030 (Hegnsholt et al. 2018, FAO 2011). FLAW is also a global phenomenon, occurring across countries of different income levels, albeit in different forms and at different rates. Overall, rates of waste have been lower, per capita, in low- and middle-income countries (LMICs), but that per capita gap is expected to narrow going forward as their incomes rise and diets shift.

A Global Framework to analyze FLAW

The Global Framework, developed by the World Bank, focuses on how a reduction in FLAW contributes to policy goals. It is a model that captures the interconnected nature of food waste along the food supply chain, including at the stages of the farm, transportation, handling, and storage (THS), processor, retailer, and consumer. It allows for exports and imports between countries and shows the relationship between reductions in loss and waste levels at various stages of the value chain and associated impacts on prices, production, consumption, and priority policy objectives. The Global Framework assesses a government's commitment of reducing food

[2] In 2011 an FAO-commissioned report by the Swedish Institute for Food and Biotechnology estimated that roughly one-third of edible parts of food produced for human consumption globally was lost or wasted, corresponding to about 1.3 billion tons of food per year. Though debated, this study is the only one providing a global estimate covering all food production sectors and stages of the supply chain (SOFA 2019). The 2015 estimate cited here is a Boston Consulting Group projection using the FAO estimate and other FAO data.

loss and waste by simulating the reduction in losses and waste rates by 50%. It then assesses how reductions at different stages of the supply chain compare in terms of their impact on outcomes of interest to support a government's key priorities.

The waste reduction scenarios, simulated by the Global Framework, show results for a series of policy priorities of interest, including farmer welfare (as measured by net profitability), food security (as measured by net consumption prices), trade (imports or exports), natural resource stress (as measured by farm production), GHG equivalent emissions, and total food waste. By jointly considering all stages of the supply chain and assessing impacts on several policy priorities at the same time, the model provides insights on the tradeoffs that result from different food waste reduction policies. This Framework compares situations of implementing food loss and waste reductions against a baseline of no interventions. A detailed analysis of costs, benefits and effectiveness of alternative interventions would be the next step towards a holistic FLAW strategy.

Food smart country diagnostics

The case of Rwanda: feeding its people

Rwanda's growing population – set to nearly double from 12 million today to 22 million in the next thirty years – will exacerbate the food security challenge. Despite significant progress since the early 1990s, Rwanda's people remain challenged by food insecurity, malnutrition and undernourishment. Rwanda's food security index lies below the average for Sub-Saharan African countries: 18.7% of Rwandan households remain food insecure, with most of them located in the western and northern parts of the country. At the same time, undernourishment affects 36.9% of the population and 35% of children are stunted (WFP 2018). Additional challenges will arise from rapid urbanization and climate change impacts. By 2050, 30% of the population will reside in urban areas (UN 2018) – compared to 18% today – with prospects of higher incomes, and a shift toward higher value diets. Likewise, Rwanda is ranked 114th globally in terms of its vulnerability versus readiness to adapt to climate change (Chen et al. 2015, ND 2017). Being primarily rainfed, higher frequency of severe droughts and outbreaks of pests and diseases increases the vulnerability of Rwanda's agriculture sector.

Rwanda loses and wastes about 40% of its food supply, totaling around 3 million tonnes of food per year. Therefore, as shown in Figure 1, food loss and waste uses 564,400 hectares of land, generates 1.2 mt CO_2 equivalent, and costs Rwanda around 12% of its annual GDP.

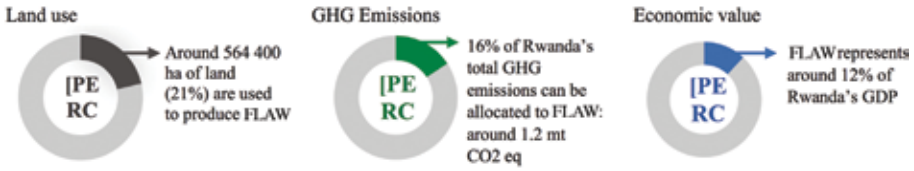

Figure 1. Impact of FLAW on various sectors. Source: USAID 2018, WBG Open Data 2018, WRI-CAIT 2018.

As opposed to increasing food production from the agriculture sector and increasing food imports, reducing FLAW would bring the country a variety of positive impacts: increased food yields from the stock of land and water already under farming, reduced pressure on the import bill by increasing the availability of domestic food, bringing benefits to remote and food-deficient households, and a reduced carbon footprint of the food supply that could potentially open doors to some sources of climate mitigation-related financing.

However, for the Rwandan Government to make fully informed decisions based on their policy priorities and considering the situational and interconnected nature of FLAW interventions described on the first section, we used the Global Framework to analyze three different commodities – a combination of staples and perishables. Each of these crops has a significant importance for Rwanda. The two staples, maize

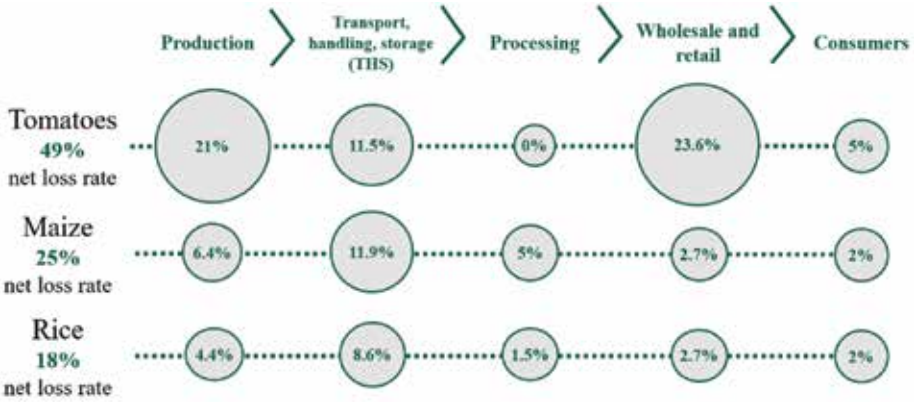

Figure 2. FLAW hotspots along the value chain in Rwanda (loss percentages occur at each stage). Source: APHLIS 2018, WRI 2019, CCAFS 2019, Kitinoja et al. 2019, Mada et al. 2014, Searchinger et al. 2019.

and rice, are specifically mentioned in Rwanda's Nationally Determined Contribution (NDC), as part of the Paris Agreement, and have therefore been prioritized. Tomatoes, a perishable, represent a large portion of perishables production for Rwanda and have experienced a growing demand from increased incomes and an expanding middle class within the country's population.

As shown in Figure 2, losses and waste occur at different locations along the value chain between the three commodities selected. Tomatoes have the largest total loss rate of 49%, followed by maize and rice, with 25% and 18%, respectively. Total loss rates are calculated by applying the respective loss rates at each stage above to the volume that makes it past the prior stage.

As discussed, demand in Rwanda for food will increase. The Global Framework and accompanying analysis propose a balanced approach to managing Rwanda's future food requirements where part of the food demand will be met by reduced food loss and waste.

Reducing FLAW of tomatoes

A key assumption is the degree of openness of the food economy, and this will depend to some extent on the food commodity being considered. Looking at production, consumption, and trade patterns, it is clear that for perishables, Rwanda is effectively a dual economy – a closed economy for remote regions with poor infrastructure and connectivity, and an open economy with access to international markets, supporting infrastructure, and a rising middle class in urban areas.

Results from the Global Framework show that for Rwanda, as a small country trader, there is an import substitution potential with cuts in losses at any stage of the value chain, shown in Figure 3. Results also show significant improvement in food security with reductions in FLAW at the retail level, compared to other stages. A cut in rates of farm losses increases farm production and hence farmer welfare, but at the expense of increased natural resource use. In addition, with reductions in FLAW at all stages, GHG emissions and total food waste decrease.

For rural areas of Rwanda, because of poor connectivity, a closed economy model may be more representative of economic conditions in the tomato (and perishables) sector. In a closed economy scenario, as shown in Figure 4, results highlight a tradeoff between farmer and consumer welfare. Cutting losses at the farm level results in lower market prices, and hence lower production, which triggers a loss in producer welfare. With these lower market prices, food security improves more significantly in a closed

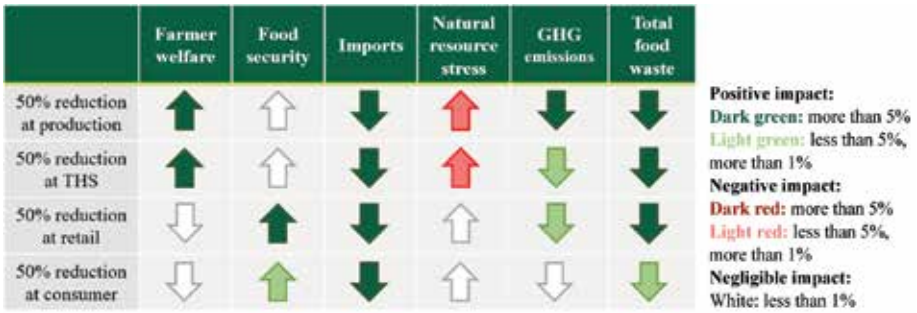

Figure 3. Tomatoes – Impact of reducing FLAW at different points of the value chain (open economy model). Source: WBG (compiled by authors).

economy compared to an open economy scenario. Finally, GHG emissions increase slightly in a closed economy scenario for decreases in rates of waste at the farm and THS levels.

Reducing FLAW of maize and rice

For staples, Rwanda is considered a small, open economy because staples tend to be transported better than perishables and Rwanda's staples import quantities have no significant impact on world prices. Similar to tomatoes, in the cases of maize and rice, a reduction in farmer loss and waste rates leads to an increase in sales coupled with a small increase in natural resource stress (Figures 5 and 6), but it is found to be partially offset

Figure 4. Tomatoes – Impact of reducing FLAW at different points of the value chain (closed economy model). Source: WBG (compiled by authors).

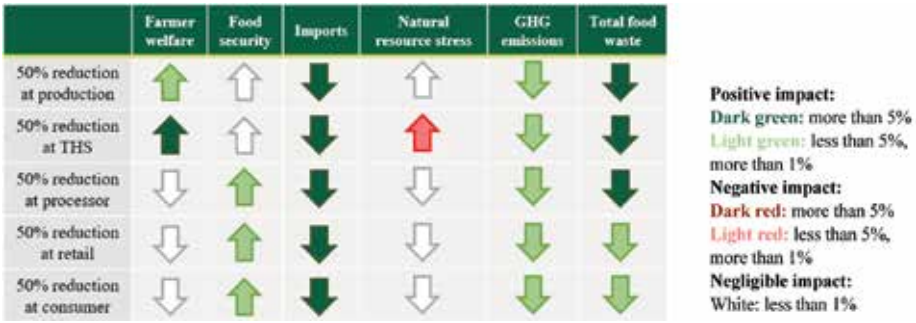

Figure 5. Maize – Impact of reducing FLAW at different points of the value chain (open economy model). Source: WBG (compiled by authors).

by a large reduction in imports. Farmers see welfare improvement with food loss reductions at both the farm and THS levels and consumers benefit through lower consumption prices. A reduction in waste rates at any point of the supply chain triggers lower GHG emissions as well as total food waste levels.

Identifying drivers and potential interventions

Food loss and waste in Rwanda is in part a consequence of the perception of risk across the value chain by multiple actors. Drivers that trigger FLAW occur all throughout the value chain. The best interventions would be measured considering their costs and their impact shown through the analysis done by the Global Framework.

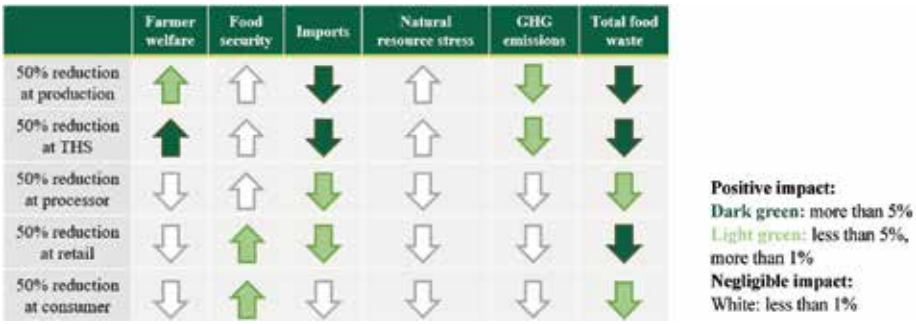

Figure 6. Rice – Impact of reducing FLAW at different points of the value chain (open economy model). Source: WBG (compiled by authors).

Conclusions

- Rwanda will not face a negative tradeoff between reducing losses and waste for any of the three commodities studied and achieving, at the same time, the six policy priorities of farmer welfare, food security, trade, natural resource stress, GHG emissions, and food waste.
- Rwanda is effectively a dual economy in the case of perishables; a closed economy in lagging remote regions with poor infrastructure and connectivity, and an open, urban economy with access to international markets supporting a rising middle class.
- The government of Rwanda seeks to transition to an export economy. This model suggests that for tomatoes, by cutting losses and waste in half, other things being equal, Rwanda can switch from a small importer to a significant exporter.

The case of Vietnam: more from less

Over the last 30 years Vietnam has experienced remarkable poverty reduction and economic growth, accompanied by significant improvements in food security. The economy transitioned from largely agrarian-focused to more diversified, with greater GDP contribution coming from the services and industry sectors over the past two decades (WBG 2016). The agriculture and food sector will remain, however, a key contributor of GDP growth and employment over the next 30 years and a critical driver of food security domestically and globally. Vietnam's burgeoning middle class in urban centers, with increased incomes and shifting diets away from staples toward proteins and perishables, as well as a booming tourism industry, is also heavily influencing the country's food demand. Vietnam now needs to shift to different patterns of growth with accompanying reforms of its food system in tandem with the changes taking place in the Vietnamese economy.

Vietnam is heavily land-constrained and needs to get more value from its relatively scarce resources, especially land. Agricultural growth has historically stemmed from expanded or more intensive use of land and other natural resources, and relatively heavy use of fertilizer and other agro-chemicals. This has led to a large environmental footprint from the sector (WBG 2016). In the future, further growth of food production and exports will need to be based on generating more from less; that is, producing higher value food items per unit of natural resources and labor utilized. But while the agriculture sector's performance has been impressive, Vietnam's once robust growth has weakened.

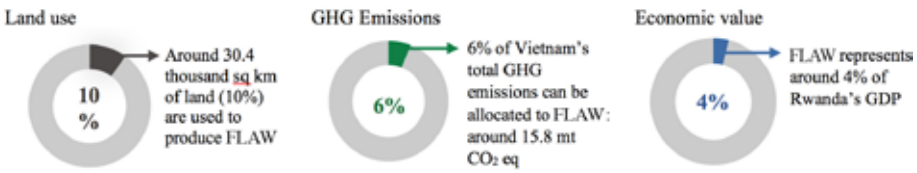

Figure 7. Impact of FLAW on various sectors in Vietnam. Source: CEL Consulting 2018, WBG Open Data 2018, WRI-CAIT 2018, FAO et al. 2019, WBG Calculations.

Food production is now facing environmental constraints to growth, and it must pivot to increase both the efficiency and sustainability of outputs to meet its development goals. One way to move towards a *more from less* objective is by reducing FLAW along the supply chain. Vietnam loses and wastes about 25% of its food supply, totaling around 27.5 million tonnes of food per year. As shown in Figure 7, this means FLAW uses 30.4 thousand square km of land, generates 15.8 mt CO_2 equivalent, and costs the country around 4% of its annual GDP.

As Vietnam is grappling with a natural resource scarcity challenge, urbanization, and climate change, the country could consider the role that food loss and waste reductions would play in helping meet its agro-food sector and development goals. Food loss and waste presents a promising option when considering the country's policy priorities, which are centered around (i) domestic availability of high quality and diversified food; (ii) global leadership in agriculture exports with a focus in high value products; and, (iii) environmental sustainability through reduced stress on natural resources, less waste contamination and lower GHG emissions.

Vietnam is a top exporter of rice and seafood, and the government is strategically shifting from the production of low value, raw exports to higher value processed exports. The share of rice in Vietnam's food calorie consumption is expected to decrease from 52% in 2009 to just over 33% by 2030, when animal products and seafood will account for 33% of caloric consumption. The global framework analyzed two main commodities: rice and farmed pangasius (catfish), to illustrate potential policy impacts when reductions of losses and waste are implemented along the value chain. As shown in Figure 8, losses and waste occur at different locations along the value chain between the two selected commodities. Catfish has the largest total loss rate of 32%, followed by rice, with 21%.

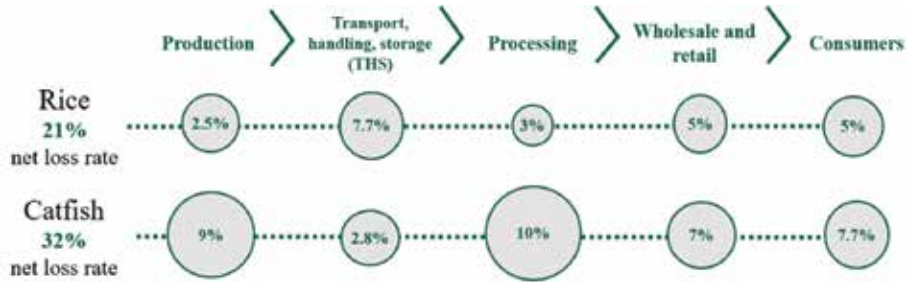

Figure 8. FLAW hotspots along the value chain in Vietnam (loss percentages occur at each stage). Source: CEL Consulting 2018, FAOSTAT 2011, and WBG calculations.

Given Vietnam's imperative to shift of to produce more from less, the driving policy priorities will likely be reducing environmental stress while meeting increasing demand for food in urban centers as well as sustaining export growth. Part of these goals will be met by reducing food loss and waste.

Reducing FLAW of rice

As Figure 9 would suggest, with a reduction of FLAW at any stage of the value chain, results highlight clear tradeoffs between improved food security, exports and natural resources stress, and a reduction of farmer welfare. The largest improvements in consumption are achieved with cuts in waste rates at the THS, retail, and consumer levels. With reductions of losses at every stage, farm production declines marginally (at most by -0.2%), as a result of lower farm sale prices, implying reduced stress on natural resources from lowered production. GHG emissions can also increase, albeit negligibly. When a 50% reduction in losses is made at the farm level, more rice flows through from the farm to the THS and processor stages, and eventually down to the consumer. Both the farm and processor stages have relatively higher GHG emission intensities compared to other stages, thereby marginally increasing GHG emissions when a reduction of FLAW is made at the farm level. On the contrary, total food waste declines significantly with reductions at any stage along the value chain.

This simulation demonstrates the viability of Vietnam's *more from less* strategy through reduced FLAW for rice production, increasing food availability for domestic consumption and international export while using the same or fewer natural resources.

Figure 9. Rice – Impact of reducing FLAW at different points of the value chain (open economy model). Source: WBG (compiled by authors).

Reducing FLAW of catfish

Like rice, food availability improves with reductions of losses at any stage of the catfish value chain. However, the impact on farmer welfare, exports, and natural resource stress depends on the stage of the supply chain where the reduction takes place. Reductions of FLAW at the farm, THS, retail, and consumer levels improve farmer welfare. However, a cut of FLAW at the processor level reduces farmer welfare, as shown in Figure 10. Exports decline marginally with the reduction of losses at the retail and consumer levels because the associated increase in catfish availability increases retail sales and consumption, and causes domestic production to decline, leading to a minimal decline in exports. Net resource stress increases in all cases, except for reductions made at the processor level. All these impacts are very small in magnitude.

Reductions in GHG emissions and in total food waste levels are explicit for catfish, with a reduction of FLAW at all stages. Vietnam can gain more food from existing natural resource use through reductions in FLAW in the catfish value chain, always increasing food availability domestically and providing more food for exports.

Conclusions

Vietnam's future food needs will be driven by a booming urban population, growth in the tourism industry, and the need to sustain exports. Rural demand for food is expected to decline. Historical gains in agricultural output came at the cost of environmental degradation and pollution, which is now an unsustainable model for Vietnam, as it has maxed out natural resources.

Figure 10. Catfish – Impact of reducing FLAW at different points of the value chain (open economy model). Source: WBG (compiled by authors).

For Vietnam, the Global Framework shows that the best strategy to increase food availability for urban centers and exports through reduced FLAW would be to cut FLAW in half at every stage of the rice and catfish food supply chains. This will be neutral with respect to natural resources and greenhouse gas emissions.

Since most impacts on policy goals are very small in magnitude for Vietnam, it is acceptable to consider a reduction of food loss and waste as neutral for farmer welfare, exports, and natural resource stress, and clearly positive in improving food availability, which matters for urban centers. While reductions in greenhouse gas emissions are evident in the case of catfish, the Framework shows that reducing losses and waste in the rice value chain is not an effective way to reduce GHG emissions because impacts are minimal or slightly negative.

Next steps

These results indicate that reducing food loss and waste bears potential benefits for Rwanda, Vietnam and Nigeria, and identifies the tradeoffs between competing policy goals implied by reductions in waste at different stages of the supply chain. Going forward, the design of these countries' food loss and waste strategies should be based on a careful analysis of alternative interventions, their associated costs, benefits, feasibility of implementation, and effectiveness in reducing losses and waste, as well as the public and private investments necessary for its implementation.

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What Needs to Happen Next

Betty Kibaara[1]

1. Introduction

As we deliberate on what needs to happen next to reduce food loss and food waste, we can pick a lesson from the Bible. Genesis Chapter 41 presents a good example: King Pharaoh had two dreams. In the first dream he saw seven fat, beautiful cows. Then he saw seven very thin cows. And the thin ones ate up the fat cows. Joseph interpreted the dream. The seven fat cows meant seven years, and the seven thin cows meant seven more years. There would be seven years when a lot of food would grow in Egypt. Then there would be seven years when there would be no food in Egypt. So Joseph told Pharaoh, 'Choose a wise man and put him in charge of collecting food during the seven good years. Then the people will not starve during the following seven bad years when very little food will grow'. Pharaoh chooses Joseph to collect the food, and to safely store it up. I believe that this was the first national grain reserve in Egypt. King Pharaoh did something about the problem – he acted and implemented food reserve strategies.

2. Role of governments in reducing post-harvest losses

Africa is not short of strategies. For example, through The Rockefeller Foundation's YieldWise initiative,[2] we supporting the development of a continent-wide Post-Harvest Loss Management Strategy at the African Union and more specific strategies for Ethiopia, Kenya, Tanzania, Zambia and Zimbabwe. While some progress has been made at the country level, in the last biannual review process only 5 countries reported having collected data on post-harvest loss in Africa.

Some of the interventions by governments include: improvement of road infrastructure; training of extension workers on post-harvest management; removal of a tax (for example to make post-harvest solutions more affordable to farmers).

There are also opportunities for development partners to scale 'successful pilots' with governments. For example, The Rockefeller Foundation is partnering with the Government of the Republic of Kenya and Makueni

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[2] https://www.rockefellerfoundation.org/initiative/YieldWise/

County, in partnership with RTI and over 20 other organizations, to develop a pest free zone that incorporates an integrated pest management. Data from this zone should assist the Kenyan government in removing the self-export ban on mangoes to Europe within the next two years.

3. Role of the private sector

The private sector continues to be a strong driver of agricultural transformation in Africa. AGRA has most recently underlined the role of the private sector in the publication *The Hidden Middle*.

- A key finding from the implementation of the YieldWise initiative was that local Small and Medium-Sized Enterprises (SMEs) marketed and handled 90% of the aggregate produce from smallholder farmers.
- In our new work on Protective Foods in East Africa we will seek the private sector to improve supply chain efficiencies to deliver safe and nutritious foods to consumers.

4. Knowledge and technology

In the YieldWise initiative we tested a diverse set of technologies for post-harvest loss reduction ranging from low-cost hermetic bags, fly traps, plastic crates, solar cooling units, agro processing equipment, and solar driers among many others. A key observation was that low-cost technologies were easily adopted.

Shortly before passing away in September 2009, Norman Borlaug, the father of the Green Revolution, famously implored the world to "take it to the farmer". What an incredible call to action. Today, Borlaug's vision statement is strong as it was 10 years ago.

5. Collaboration

Israel is a world producer of many commodities. For example, tomato yield is 300 tonnes per hectare, compared to an average of 50 tonnes per hectare worldwide. The country also leads in post-harvest handling: it records 0.5 per cent of grain storage loss, compared to 20 per cent worldwide. How did they achieve 0.5% grain loss? Key tenets were government commitment, effective government, innovation, farmer organization and market-led approach.

We all have an opportunity to make a difference: for King Pharaoh it was a 7-year window!

For all of us, we have more than 7 years – together, we can make a difference and meet the target of halving post-harvest loss in the next 10 years.

V: INITIATIVES FOR COMPLEMENTARY AND JOINT ACTION BETWEEN CIVIL SOCIETY AND CORPORATIONS

United Against Food Waste

Selina Juul[1]

What can the Holy See, the Vatican and the Catholic Church do to engage in the fight against food waste?

Food waste is a global scandal. There are over 7 billion people on this planet, of which 795 million are starving. Yet, annual food losses and waste are 1.3 billion tons of food – or enough to feed 3 billion people. In 2013 His Holiness Pope Francis said: *"Throwing away food is like stealing from the table of those who are poor and hungry"*.

Focusing on climate change is becoming more and more important in our everyday lives, and climate change is impossible to overlook. Many citizens of the world feel uncertain about what they need to do to reduce their personal CO_2 emissions. Fortunately, stopping food waste is among the lowest-hanging fruits.

According to the UN, approximately one-third of global greenhouse gas emissions comes from food production, which includes agriculture, livestock and land use change, thus making food production the world's third largest CO_2 emitter. Also, according to the UN, a third of all the world's food is either lost or wasted. According to Paul Hawken, one of America's notable environmentalists and the initiator of *Project Drawdown*, which is the most comprehensive plan ever proposed to reverse global warming, reducing food waste is ranked third among the world's top 10 climate solutions. Individuals can therefore make a big difference to climate, resources and the planet by reducing their food waste.

It's time to end the global food waste scandal. It's time to actively engage the 1.313 billion Catholics all over the world to take action to stop wasting food. The Stop Wasting Food movement, World Resources Institute and WRAP (The Waste and Resources Action Programme) propose to team up with the Catholic Church to create a global campaign against food waste aimed at, and engaging, the 1.313 billion Catholics all over the world. The campaign could be launched with the approval of and support of the Holy See, the Vatican and the Catholic Church and even perhaps His Holiness Pope Francis.

[1] Chairman of the Board and Founder of Stop Wasting Food movement - www.stopwastingfoodmovement.org

The Stop Wasting Food movement, World Resources Institute and WRAP suggest that the Holy See, the Vatican and the Catholic Church create a joint global campaign against food waste aimed at and engaging the 1.313 billion Catholics all over the world. There are examples of successful campaigns which could be developed, adapted and built on to create a campaign tailored for the Catholic Church. The two main global examples are the *Stop Wasting Food* campaign and the *Love Food Hate Waste* campaign.

Such a joint global Catholic Church campaign against food waste could be a combination of: 1) messages (raising awareness and call to action), 2) messengers (who deliver the messages), 3) modes (how the messages are communicated – a mix of methods) and 4) means (how one makes it easy for people to take action, tips etc.).

The campaign should be on more than one level – some led by His Holiness Pope Francis but also implemented locally by individual Churches (tailored to local situations alongside some high-level messaging by His Holiness Pope Francis and the Cardinals).

The campaign needs to be aimed at both members of the Catholic Church reducing their food waste but also with them acting as role models in their local communities to help drive community-wide reductions. The campaign needs to address different countries in different ways, thus there should be some key stages: 1) developing the approach, 2) pilots in some chosen countries and evaluation and, 3) wider roll out and implementation in more countries.

What can the Holy See, the Vatican and the Catholic Church do to engage governments of the world in the fight against food waste?

1) Advise and engage the governments of the world to set up *National Food Waste and Food Loss Prevention and Reduction Targets.* Those Reduction Targets must be aligned with UN Sustainable Development Goal 12.3 as well as the European Commission's Circular Economy Package.
2) Advise and engage the governments of the world to initiate *National Knowledge Centers on Food Losses and Waste.* Those must provide and share national and international best practices in Food Waste and Food Loss Prevention and Reduction. The most effective ones can be studied and replicated.
3) Advise and engage the governments of the world to initiate *National Food Loss and Waste Prevention Funds* to provide ongoing financial support for national initiatives, projects and organizations against food waste in the entire value chain from farm to fork – from researchers to

NGOs and campaigners. If there is no money for the fight against food waste, the fight against food waste will die out.

4) Advise and engage the governments of the world to *focus on the prevention of food waste* rather than on reducing food waste. The prevention of food waste is, for example, prevention of the overproduction of food. As for reduction, it is, for example, giving surplus food to charities. Improving forecasting accuracy and planning process they actively increase the efficient utilization of food. It is good and important to donate surplus food to charities, but it does not prevent the root cause: the overproduction of food. And it is even more important to work on preventing the overproduction of food to begin with. However considerate it is when a food producer donates five pallets of surplus food to a local charity, it is still a symptom treatment, it does nothing about the root of the problem. Thus, the problem must be solved at its root – and the overproduction of food must be addressed.

Short overview of successful interventions and organizational solutions to tackle food losses and food waste, including business cases, partnerships, scale-up solutions, innovation and alliances of different actors

Successful intervention 1 – Ugly vegetables:

Three hundred and seventy tons of "ugly" vegetables saved in Denmark in just two years. Sale of ugly vegetables in Denmark is on the rise: ugly, bendy, natural-looking cucumbers, tomatoes, Ugly Tomato Ketchup and other imperfect vegetables are now being sold in Danish supermarkets. In the last two years (2018-2020), Danish consumers bought 370 tons of "ugly" and imperfect vegetables, which otherwise would have ended up as farmers' garbage.

The national collaboration is powered by the Stop Wasting Food movement, REMA 1000 Denmark retail chain, Salling retail chain and Denmark's biggest farmers, Alfred Pedersen & Søn ApS, in collaboration with Gartneriet Ostervang Sjaelland, GASA Odense and GASA Nord Gront Amba. Ugly vegetables are being sold in supermarkets and they are 15% cheaper than "normal" vegetables – and at the same time the initiative supports the Stop Wasting Food movement. A study conducted by Epinion for the Stop Wasting Food movement shows that over half of Danes (55%) prefer to buy a food product if it shows that it contributes to less food waste. The initiative received a lot of media attention in Denmark and internationally. This successful collaboration will continue and it will expand to several more food brands.

Successful intervention 2 – Cookbook with H.R.H. Princess Marie

Denmark's biggest enthusiast against food waste, well-known chefs and Her Royal Highness Princess Marie of Denmark have teamed up for a new cookbook against food waste, which was published at the end of 2019. The cookbook is aimed at families, inspiring greater respect for food, saving time and money and, at the same time, helping the environment.

Every year, over 700,000 tonnes of good, edible food are thrown away in Denmark. The biggest food wasters are households, and especially families with children, who face the greatest challenge to use up all their food. Every year, an average Danish family wastes food worth 7,200 DKK – equivalent to 964 Euro or 1,077 USD. Tangible, easy tools are needed to help families avoid food waste and to put the trash bin on a diet. That's why the Founder of Stop Wasting Food movement, Selina Juul, brought together some of Denmark's most dedicated food waste fighters: Her Royal Highness Princess Marie of Denmark, renowned TV chef Timm Vladimir, food entrepreneur Anh Lê, gastronomic superstars Francis Cardenau and Michel Michaud, as well as cookbook author Louisa Lorang. Together, they have written a useful simple cookbook with a focus on food waste, entitled *Food with Respect – A family cookbook that reduces food waste*, published today by Gyldendal publishing house.

All the recipes in the book are based on food products that are among the most wasted types of food in Danish households. *Food with Respect* also provides guidance for storing leftovers, smart meal planning and food shopping – all in order to reduce food waste. The book's 80 recipes in total were prepared by the aforementioned contributors. Her Royal Highness Princess Marie of Denmark wrote the book's foreword and contributed with her own recipes. The cookbook *Food with Respect* gives Danish families good, easy and hands-on tools to become better at using food, saving money and helping the environment.

The book is a great collection of good advice, recipes, tips and suggestions on how a family can become even better at using all the food. Avoiding food waste is about showing more respect for food – and for the whole enormous process that provides food on our plates.

Each sold copy of *Food with Respect* triggers a donation to DanChurchAid, an NGO working to fight hunger in Africa.

The book will be translated into international languages and has already generated big national and international attention. The book is also a Danish Winner of the 2020 Gourmand World Cookbook Awards in the "Family" category.

Successful intervention 3 – Christmas Surplus food

The annual "Christmas Surplus" national initiative was founded in 2015 by the Founder of Stop Wasting Food movement, Selina Juul. The Stop Wasting Food movement and its NGO partners, for example Danish People's Aid, collect surplus Christmas food from 300+ REMA 1000 supermarkets every December 23rd. It is good Christmas food that customers won't buy after supermarkets reopen after Christmas. The food gets collected by volunteers in 300+ REMA 1000 supermarkets and around 10 food insecure families per supermarket arrive on the evening of December 23rd to collect free surplus Christmas food worth 80 Euro per family. In one day, over 30 tons of food is saved due to the "Christmas Surplus" national initiative.

The annual "Christmas Surplus" national initiative can be replicated before any other holiday where the supermarkets are closing for the holidays – Christmas, Eid, Easter, etc. – and it can be replicated all over the EU – as well as all over the world. Since its initiation in 2015, the "Christmas Surplus" national initiative has helped feed approximately 50,000 food insecure citizens and saved approximately 150,000 tons of surplus food from going to waste.

Action plan:

- Every December 23rd, Danish supermarkets turn into local food banks.
- Volunteers from Stop Wasting Food and its partner NGOs collect surplus food in the supermarkets, which otherwise would be wasted, just before the supermarkets close for the holidays.
- 10 food insecure families per supermarket show up on the evening of December 23rd and collect the food, which is handed to them by volunteers.
- 30 tonnes of surplus food are saved in just one day and over 10,000 food insecure people get free food.

Why is "Christmas Surplus" successful?

- More and more NGOs, charities and retail chains are copying the initiative – thus more and more food insecure citizens are helped – and more and more food is being saved.
- It is a very cost-effective initiative powered by volunteers and supermarkets. The only thing necessary is 5-6 months of planning ahead.
- It attracts a lot of positive media attention and raises awareness about food waste.

– "Christmas Surplus" is empowering people and ensuring inclusiveness and equality by involving volunteers of all races, nationalities and religions in a common goal to stop wasting food, saving food and feeding food insecure people.

Main insights gained from "Christmas Surplus"

– Need to collaborate with professional NGOs who have access to approved data of citizens below the poverty line, in collaboration with municipalities and authorities.
– It is important to only give surplus food to citizens below the poverty line, who are approved by professional NGOs, municipalities and authorities – not to people off the street claiming to be poor.

Great support

– The initiative even won Royal support by H.R.H. Prince Joachim of Denmark, H.R.H. Princess Marie of Denmark, and the Danish Minister for Environment and Food through a fundraising Charity Dinner in 2016.

Conclusion

– "Christmas Surplus" can be upscaled anywhere in the EU and the world in the days before Christmas, Easter, Eid and other holidays, before supermarkets close.
– It is a very tangible, hands-on approach to stop food waste and to feed food insecure citizens.
– It generates a lot of positive media attention, has a very big potential for collaborations and sponsorships. It is a very positive way to raise awareness about food waste and, at the same time, save food and feed food insecure citizens.

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Fighting Food Waste as a Logical Choice

Santiago Guglielmetti[1]

The big question we must face in this struggle is: how do we tackle environmental problems such as FLAW (Food Loss and Waste) if everyone is just struggling to make ends meet.

In Latin America, and many other developing regions, it is sometimes tricky to introduce an environmental problem such as Food Waste on the agenda. Economic needs and the urgency to just survive are usually a priority over the environment. Or they think of it just as a First-World-Issue, nothing that should concern them. The consequences of food waste aren't immediately visible, and postcapitalist ideas are not yet settled in our region. Because of this, it can be hard for NGOs or civil society actors fighting against it to be heard and, for governments, to have the incentives to tackle the problem at its root.

If we keep thinking of the economy and the protection of the environment as a zero-sum game, we end up in a vicious circle, where the need for growth takes over at the expense of our planet and our future. We need to break this cycle and focus on creating incentives for less harmful behaviours. WINIM is an example of an answer to this dilemma in the worldwide battle against food waste.

WINIM is a mobile app that connects our users with a variety of shops, local producers and restaurants who offer their unsold food – that would otherwise be wasted – at a discount price. And it is quite simple to use: our users just open their app on their cell phones, pick a dish they want and either order it with take away or by delivery.

We call our app a Win-Win-Win business model: first, the shops get to make an extra income with the food that currently ends up in the bin despite being perfectly fine; secondly, our users get to enjoy delicious food at amazing prices; and third, above all, we get to help our planet by tackling food waste and raising awareness on this issue.

This way, we create real incentives to all actors in our society to join the fight against food waste. Meanwhile, we are growing strong: in less than 9 months we already have more than 500 partners and are planning to expand. WINIM and similar apps (like Too Good To Go or Karma in

[1] WINIM co-founder.

Europe) around the world are, therefore, a good example that *ecologic and sustainable business models can also be profitable – that the two are not incompatible.* As it is properly said in *Laudato si'*: we have to find a comprehensive perspective towards the environment that includes our societies, their cultures and lifestyles.

Our initiatives may not be able to win the battle against food waste on their own, but it is a simple way to get more people to understand and join the sustainability cause. At WINIM, we fully believe in the idea that by making small changes in our daily habits, such as the way we purchase food, we can help to significantly reduce food waste.

Indeed, in real estate it is a common cliché to say "location, location, location". Well, in WINIM we believe that if we want to make real change we should focus on "communication, communication, communication". We have to communicate the issue and our proposed solutions in such a way that it is *the logical choice* not to waste food.

We should accept if someone does not care about the environment; we can try to communicate as best we can why he or she should be concerned about it. But if we want immediate action, we have to show them that they are also wasting their money, time, work and effort. For example, if you have a supermarket chain and you don't use an app such as WINIM to cut your food waste, then you are wasting money; if you baked 20 muffins and wasted 5 instead of selling them at a discount, then you are wasting your work and effort; and so on. We must concentrate on proper *storytelling*.

In conclusion, how do we tackle environmental problems such as FLAW (Food Loss and Waste) if everyone is just struggling to make ends meet? By giving the right incentives for everyone to cooperate and join us. We need to tackle the problem and if we only rely on a moral stance, at the end of the day all main actors in our society will keep on wasting. But, if we show that *it is not logical* to waste, then change can be finally achieved.

Fight Food Waste Cooperative Research Centre – A National Public-Private Partnership to Reduce Food Loss and Waste in Australia

Steven Lapidge[1]

Introduction

The Australian Fight Food Waste Cooperative Research Centre (FFW CRC) is a AUD$120 million (75 million) 10-year food waste Research, Development and Extension (RD&E) Public Private Partnership that commenced on June 1, 2018. The organisation involves 58 participants from across the food supply chain in Australia, as well as the Waste and Resource Action Programme from the United Kingdom. The FFW CRC purpose is for *an Australia without food waste*. It aims to achieve this by uniting science and industry to REDUCE food waste across the supply chain, TRANSFORM unavoidable food waste into innovative products, and ENGAGE with industry and consumers to deliver behavioural change. Through delivering on the above aims the FFW CRC will increase industry profitability, address food insecurity and enhance Australia's reputation as a sustainable food producer.

Background

A thriving, efficient and sustainable food industry is central to Australia's economy, regional job security and prosperity, yet reportedly 40% of all the food produced in Australia goes to waste. In 2015 food waste was estimated by the author to amount to AUD$20 billion (12.5 billion) across the value chain. In November 2017 the Australian Government launched the National Food Waste Strategy that committed the government to Sustainable Development Goal 12.3, to halve food waste by 2030. In March 2019 the Australian Department of Environment released the National Food Waste Baseline study, which reported that Australia generated 7.3 million

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tonnes of food loss and waste per annum that was not being diverted to food rescue or animal feed, with 31% generated in primary production, 24% in food manufacturing and 34% by households. The result of the benchmarking study is that Australian per capita food waste is 298 kg per person per annum, which will need to be reduced to 149 kg per person by 2030 to achieve SDG 12.3.

Strategic objectives

The Fight Food Waste CRC brings together industry, research and the community to capitalise on Australia's food waste opportunities. Winning this fight could save Australia $20 billion per annum in wasted food while increasing industry profitability and reducing food insecurity, as well as enhancing Australia's reputation as a sustainable food producer.

The overarching strategic objectives of the Fight Food Waste CRC are to deliver:

- A transformation in the way Australian industry and consumers view food waste as well as contribute to food rescue
- A suite of new tools and technologies for extracting the maximum value out of primary production, food manufacturing, supply chains and product sales, whether through supply chain innovation or waste transformation
- Reduction in food waste entering landfill and associated greenhouse gas emissions
- Future industry professionals skilled in capturing opportunities identified by industry.

Participants

The Fight Food Waste CRC currently involves 59 participants that are listed below, including 11 public state government departments, councils and utilities; 21 private companies; 18 peak industry organisations; 8 universities and one international participant. All participants put in cash funding and/or in-kind contributions (staff and non-staff/facilities) or both. The AUD$33 million cash and AUD$57 million in-kind raised by participants was matched by AUD$30 million from the Federal Department of Industry, Innovation and Science CRC Program. The organisation is open to new industry participants and international RD&E collaborators.[2]

[2] *Public*: 1. Australian Capital Territory Transport Canberra and City Services; 2. ChemCentre, Western Australia; 3. Green Industries South Australia; 4. New South

Outputs

The Fight Food Waste CRC aims to deliver:

- New sources of revenue and market growth for food companies.
- Less waste of resources throughout the supply chain from grower through to consumer.
- Less food waste ending up in landfill.
- More donated food to feed hungry Australians.

The key outputs of the CRC will be delivered through the three RD&E programs:

REDUCE food waste throughout the supply chain by:

- Delivery of supply chain analysis tools
- Framework for optimal packaging design
- Innovative supply chain and packaging solutions
- Options to optimise food rescue.

Wales Environmental Protection Agency; 5. Primary Industries & Regions South Australia; 6. Queensland Department of Agriculture & Fisheries; 7. Queensland Department of Environment & Science; 8. Queensland Urban Utilities; 9. Sustainability Victoria; 10. Western Australia Department of Water & Environmental Regulation; 11. Whitsunday Regional Council. *Private*: 12. Australian Country Choice Production; 13. Chameleon Asset Protection; 14. Empauer; 15. Entopia Biotechnologies; 16. FAVCO/Green Valley; 17. Foodbank Australia; 18. Gretals Australia; 19. Honey and Fox; 20. KPMG; 21. Mitolo Group; 22. OzHarvest; 23. Pacific Coast Produce; 24. Peats Soils and Garden Supplies; 25. Piper Alderman; 26. Planet Protector Packaging; 27. SA Potato Company; 28. Sampano; 29. Swisse Wellness; 30. Thomas Foods International Fresh Produce; 31. Woolworths Group; 32. Zerella Fresh. *Peak Industry Organisations*: 33. Abalone Association of Australasia; 34. Abalone Council of Australia; 35. Australian Council of Prawn Fisheries; 36. Australian Food & Grocery Council; 37. Australian Institute of Food Science & Technology; 38. Australian Institute of Packaging; 39. Australian Organics Recycling Association; 40. Australian Packaging & Processing Machinery Association; 41. Australian Food Cold Chain Council; 42. Bowen Gumlu Growers Association; 43. Central Coast Industry Connect; 44. Fisheries Research & Development Corporation; 45. Food and Fibre Gippsland; 46. Food Innovation Australia Limited; 47. Food South Australia; 48. Potatoes South Australia; 49. Regional Development Australia Murraylands & Riverland; 50. Toowoomba and Surat Basin Enterprise. *Academic*: 51. Central Queensland University; 52. Curtin University; 53. Queensland University of Technology; 54. RMIT University; 55. Swinburne University; 56. University of Adelaide; 57. University of Queensland; 58. University of Southern Queensland. *International*: 59. Waste & Resource Action Programme (United Kingdom).

TRANSFORM unavoidable food waste into innovative products by:

- Identifying and prioritise commercially valuable products from waste streams
- New technologies for waste transformation
- Decision support tools
- Regulatory options to promote investment in waste transformation.

ENGAGE with industry and consumers to deliver behavioural change:

- Educating future industry professionals
- Industry dissemination and skills training
- Facilitating household and business behaviour change.

The Fight Food Waste CRC will deliver its RD&E programs through two key focus areas:

Deliver the Grant Agreement

We will first establish our initial 30-project research, development and extension program based on the best science and expertise with our existing participants. We will then develop and deliver new projects with existing and new participants that ensure we effectively deliver on all Grant Agreement performance milestones that we have with the Australian Government.

Deliver future initiatives

We will identify and target additional food loss and waste opportunities based on the National Food Waste Baseline and other key reports that will deliver significant food waste reduction and industry benefits to help achieve SDG 12.3. Additionally, we will scope and potentially develop a 10-year national behaviour change program that targets the entire food system, particularly consumers, with the Australian and state and territory governments and industry that reduces and prevents food waste from entering landfill.

Research, development and extension impacts

To monitor its impact on food waste reduction and industry profitability the Fight Food Waste CRC has established an Industry Impact Committee. The objectives of the Industry Impact Committee are to:

- Maximise the economic, environmental & social returns from food waste for industry participants and to develop the circular food economy.

– Facilitate the achievement of UN Sustainable Development Goal 12.3.
– Undertake regular reviews of stakeholder engagement.

Based on the predictions of the Australian Government CRC Program Impact Tool, which was prepared for the Stage 2 Full Business Case and reviewed extensively by KPMG Australia, the Australian Government can expect a return on their investment of at least 4.8:1, with individual program Benefit: Cost Analyses ranging from 4.6:1 for TRANSFORM with its higher establishment and usage costs, to 6.5:1 for ENGAGE.

In total the Fight Food Waste CRC expects to deliver risk adjusted, discounted (NPV) net economic benefit of AUD$2.0 billion between 2018 and 2033 based on the Impact Tool. This is deemed to be conservative, as achieving the NFWS target of 50% food waste reduction by 2030 would deliver AUD$10 billion in economic benefits per annum. By comparison, WRAP in the UK has delivered at least £13B (AUD$23B) in economic benefit since its inception in 2005, indicating that a much greater impact than that predicted is possible in Australia.

Too Good To Go

Philippe Schuler[1]

With 2020 we head into a new decade, giving us just a little more than ten years to reach the SDG Target 12.3 of halving food loss and waste across the entire supply chain.

Many countries, cities, municipalities, and businesses have set clear targets and methodologies to achieve this, and it is clear that a certain sense of urgency is needed from everyone, so we are acting in unison and fighting food waste *together*.

Collaboration across the supply chain, countries and business sectors will be vital to ensure that the drastic systemic changes we need are implemented across our food system. To encourage this solutions-led approach to the challenges we face, Too Good To Go has invested in complementary and joint actions and initiatives, and we know that every action we take is made all the more powerful when we have a partner standing beside us. We believe there are three key points to consider when asking how we get this work done:

- The special position we are in
- Our solution and solution-led thinking
- Joint actions as the key for success.

The special position we are in

It is no longer a secret that we are facing a climate crisis, but as well as the rising greenhouse gas emissions, and changing and unpredictable weather patterns we all hear about, scientists predict that key tipping points will be reached within the next decades, just at the time we reach new milestones in world population.

Humanity is growing at a faster rate than ever before and it is predicted that by 2050 we will reach 10 billion people. This means that we will have over three billion more people to feed, *as well as* ensuring that the 820 million undernourished people are taken into account. We will need to find ways to drastically sustain this growing population.

[1] Global Movement Coordinator at Too Good To Go.

But we are in a special position, because we have identified the challenges, and have the chance to act.

Reducing, and at best preventing, food waste, means we will be able to directly tackle all of these challenges head on. By wasting food, we are not only wasting the beautiful produce in our hands, but also the precious resources that it took to produce, process, refrigerate and transport it from A to B. Yes, it is a moral issue that has detrimental consequences for the economy, society, and our planet.

We are at a unique tipping point in history, and governments, businesses, banks and charities are more aligned on what needs to be done than ever before.

When we act as one, we see a bright future.

Our solution and solution-led thinking

Scalable solutions are the catalysts of change. They multiply and create change from sector to sector; country to country. As an accredited B-corp, we are recognised as an organisation using business for good. By building a Movement Against Food Waste, we are ensuring that all actors work hand in hand across the system, so that we can achieve our vision of a planet with no food waste.

We know that it will not be enough to act alone in this endeavour: our solution is in *partnerships.* We aim to inspire and empower everyone to take action and fight food waste together. Our solution is a behavioural and culture shift: *together* means everyone in society, ranging from the younger generations, businesses, NGOs, politicians, all the way to consumers.

Marketplace

Our B2C app provides a simple and effective tool that enables consumers to save surplus food from retail and food services. It is a hugely gratifying experience in a world where people mostly want to make a difference, but find it hard to know whether they really are. On our marketplace, consumers get delicious food at attractive prices, partners reduce waste and get exposure to new consumers, and we help the environment by reducing waste – win-win-win. Now established in 14 countries, it is a story of a successful, solid business model that is both innovative and scalable. To date, we have helped to save 30 million meals from going to waste, together with over 45,000 partners and a community of more than 22 million users. And we are not stopping here... by 2025 we want to have saved 1 billion meals from going to waste.

Households

More than half of all food waste in the EU happens at home. Consumers have simply lost respect for food, and this has been fostered by many players in the value chain. Food has become so abundant, and relatively low cost, that we expect shelves to be full with perfectly-looking produce at all times; we jump for the cheapest deals across aisles; and we are disassociated from the source and the resources it takes to produce it as food travels longer and longer distances. At home, we have lost track on how to best store, prepare, repurpose, or interpret the shelf life of food items. We believe it is essential to help people value food again and to teach everyone easy tricks and tips to reduce food waste at home. A recent study by Wageningen University & Research has shown that users of our app are highly conscious and motivated about food waste, and that using the app enforces their awareness and supports them to prevent food waste; through our application, we impact and inspire people directly to fight food waste.

Businesses

We know that we are currently only scratching the surface when it comes to eliminating global food waste. We are continuing to expand our business geographically and are also looking for new opportunities horizontally and across the value chain. Besides working with restaurants, supermarkets, hotels, and bakeries, we have now expanded the use of our application with wholesale, canteens and food producers. We work with Metro AG across nine countries in a partnership that includes saving meals in their wholesale stores, staff canteens, restaurants, and alongside their own HoReCa customers. Together with Unilever Food Solutions, we have introduced our digital solution for chefs to fight food waste in their kitchens and HQ canteens to help avoid food waste at group level.

Schools

The younger generations will be the change makers of tomorrow. We have seen that impacting students and school age children also means directly influencing the behaviour of the rest of the family. We believe that educating them on this issue will be key to securing the sustainable future we want for humanity and our planet. By curating free educational toolkits that include case studies, teacher guides, courses, and exercises for all ages, we make sure that the issue of food waste is entering the classroom. This also entails partnering with FAO and the Save Food Initiative to push this

educational content across different countries and equip students with the right tools they need to fight food waste.

Public affairs

In order to achieve change at a wider scale, the adoption of legislation and policies designed to actively reduce food waste is crucial. We are actively encouraging countries to include food waste reduction targets in their Nationally Determined Contributions towards climate change mitigation. We are also inspiring regional governments and cities to set clear goals in developing circular and sustainable food systems within their respective ecosystems.

We also make sure we are regularly contributing to policy discussions with the European Union, to achieve tangible and measurable legislative commitments on food waste reduction across the entire continent. The EU will soon enshrine into law its ambition to become the first climate-neutral continent by 2050, through its 'Green Deal' project, and is looking for measures that can help to significantly reduce greenhouse gas emissions. We need to ensure enforceable food waste reduction targets for every country, and we have started to take action across several of the countries in which we operate.

In Denmark, Switzerland, and Germany we have successfully launched date labelling campaigns with food producers and retailers, who have committed to amend the 'best before' dates on their products, with the aim of informing consumers that food is still edible, and 'often good after' the expiry date on the package. Consumers should instead rely on their taste, smell, and vision, and be better informed of the meaning of different types of date labels.

In France we have officially launched, with the support of the Ministries of Agriculture & Food, and Environment, the 'Pact on Product Consumption Dates' that brings together key food organisations in an open dialogue to achieve the enforcement of 10 concrete, measurable and ambitious commitments made through the Pact. These commitments will ensure, among other goals, a better understanding of product consumption dates, the definition of common best practice amongst professionals and the recovery of products excluded from retail channels. They are across the supply chain and intended to be Europe-wide.

Joint actions as the key for success

We truly believe that only by fighting food waste together we will be able to achieve our vision of a planet with no food waste. Our partnerships,

and consumers actively saving meals every day, make the movement so strong. Food is wasted across the entire supply chain and each actor has a responsibility to do their part, and no longer work in silos around the issue.

Interestingly, despite the global consensus that business has a massive responsibility to now do things differently, we have a challenge on our hands when initiating such collaboration. Private entities such ours that provide solutions and incentives to bring about change, are still, in the eyes of some, representative of the uncaring businesses practices that have caused this issue in the first place. Some may ask: why should we include them in discussions? Our answer is transparent conversation and collaboration. We need businesses in the fight against food waste as much as we need any other player.

One cannot rely on NGOs alone to clean up the mess that was left behind. With a lack of funding, they are facing the impossible task of solving the problem on their own. The opportunities to make a positive impact are limitless, and the next decade will show joint actions as the only way to meet targets and ensure a transformative and fundamental system change.

We are incredibly proud and thankful to have been invited to this forward thinking conference that has encouraged a global conversation by gathering various entities from all sectors to engage in an open dialogue. Only by working together and thinking in a solutions-led way can we bring an end to food waste.

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Addressing the Food Loss and Waste Challenge – a WRAP perspective

Marcus Gover,[1] Richard Swannell,[2] Christian Reynolds[3]

Introduction

Unsustainable production and consumption of food constitutes one of the biggest environmental threats to our planet. Eliminating food loss and waste to the largest extent possible – at all stages from producer to final consumer – stands out as an urgent and indispensable step towards more sustainable food systems. In fact, recent research shows that tackling food waste is the third most effective intervention to reduce greenhouse gas emissions, the most important priority of our time (Hawken 2017).

The United Nations Sustainable Development Goal (SDG) 12.3 sets out a specific target on food waste to 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, by 2030. In order to measure global progress towards SDG 12.3, two indices have been proposed: the Food Waste Index (Global Innovation Exchange 2018) and the Food Loss Index (Fabi and English 2018).

Successfully achieving SDG 12.3 requires new thinking, new partnerships and new actions to reduce resource use, and increase the efficiency of the production, preservation, processing and distribution of food at the producer, intermediary, processor and wholesale level. It needs wider education, increased awareness, and behavioural change among citizens, retailers, and policy makers across the globe. The goal is to produce more food to feed the world's expanding population, while reducing land use, fertilizer applications and critically dramatically reducing greenhouse gas emissions (Flanagan et al. 2019).

To help deliver this critical target, Champions 12.3 has been formed (Champions 12.3 2016). It is a unique coalition of executives from governments, businesses, international organizations, research institutions, and civil society dedicated to inspiring ambition, mobilizing action, and ac-

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[2] WRAP Development Director for international and new product development strategies.

[3] Technical Specialist in international food sustainability, WRAP.

celerating progress toward achieving SDG Target 12.3. It has produced a trajectory for delivering 12.3, what needs to happen and by when that provides the critical "roadmap for change" (Champions 12.3 2017a).

In this paper we provide the perspective of WRAP (the Waste and Resources Action Programme) on the economic, social and environmental case for action, what research shows works in driving change and how these activities might be scaled to deliver SDG 12.3. WRAP is a not for profit organization, based in the UK and working in more than 20 countries worldwide, that aims to help people and planet thrive. WRAP is a leader in tackling food loss and waste effectively and supporting international food loss and waste prevention projects – including Champions 12.3. Since 2007, WRAP has been a partner in many global food loss and waste projects and initiatives and has co-authored key reports. This includes EU projects such as FUSIONS (2016) and REFRESH (2020a), as well as the development of the Food Loss and Waste Accounting and Reporting Standard (World Resources Institute 2016).

In the UK, WRAP, food businesses and other partners have delivered large-scale interventions to reduce food waste across supply chains, and households for more than ten years (since 2007), supported by UK Governments and by businesses and enabled by a series of collaborative public-private partnerships. WRAP's work in the UK with its partners has helped reduce food by 27% or 1.7 Mt/y saving food worth £5 billion/year. Cumulatively the total food waste reduction has been 18.5 Mt worth US$50 billion (WRAP 2020a).

This paper highlights the importance of tackling food loss and waste, using specific recent examples from the UK and Mexico. Second, we discuss the business case for addressing food loss and waste. Thirdly we highlighting two approaches that research shows can be particularly effective at driving change at scale, and we conclude by proposing a three-point plan for tackling food waste to deliver SDG 12.3 over the next 10 years.

The importance of tackling food loss and waste

Food loss and waste is a global issue, with approximately one third of all food produced for human consumption lost or wasted, a staggering 1.3 billion tonnes (Gustavsson et al. 2011). Food waste contributes to climate change and represents a waste of scarce resources such as land, energy and water. Indeed, the 2019 IPCC report on Climate Change and Land has now estimated that global emissions associated with food loss and waste are at 8-10% of total anthropogenic emissions in CO2e (IPCC 2019). Furthermore, food

waste in Europe accounts for 15 to 16% of Europe's total emissions from the entire food supply chain (Scherhaufer et al. 2018). The EU 2030 climate and energy framework commits to at least 40% cuts in greenhouse gas emissions (from 1990 levels). Therefore, reduction and prevention of food waste represents a significant step necessary for the EU and the wider international community to meet current emissions reduction commitments.

The value of lost and wasted food is huge, at $940 billion, nearly double the turnover of Walmart, the world's biggest retailer (Walmart 2019; FAO 2020). In the EU alone the cost of food waste is estimated to be around EUR 143 billion (Stenmark et al. 2016). This includes costs to producers, who leave produce un-harvested; processors, who discard edible products that do not adhere to market size and aesthetic standards; retailers, who lose products due to spoilage during transport, and throw away unsold products; and households, who waste edible food for a variety of reasons including spoilage, lack of knowledge, over-purchase, and confusion about best-before/consume-by dates (Quested et al. 2013). In addition to the monetary cost of the food wasted, there are also additional financial costs for collecting, managing and treating food waste.

Food waste highlights the inequity of our food system. While 88 million tonnes of food are wasted yearly in the EU, in 2017, 112 million people in the EU were living in households at risk of poverty or social exclusion (22% of the population), with 5.8 million people (7.4% of the population) living in severely materially-deprived circumstances, meaning they have limited access to suitable food and healthy diets (Eurostat 2019). This is repeated at the global scale with 820 million people in the world hungry today (1 in every 9 people), while over 2 billion are now obese – linked to unhealthy diets, and overconsumption of food (Ng et al. 2014). By 2050 it is estimated that there will be an additional 2 billion extra mouths to feed (FAO 2009). Reductions of food loss and waste combined with gleaning, food rescue, and redistribution activities can be used as part of a whole systems approach to address the huge problem of hunger and food insecurity (Watkins and Simister 2017).

Finally, food waste is also a major indirect cause of biodiversity loss (FAO 2013; Feldstein 2017). This is due to uneaten, wasted food compounding unsustainable agriculture practices and agricultural expansion into wild areas (e.g., deforestation), as well as unsustainable fishing, and aquaculture. Likewise, a quarter of all agricultural water – over 17 percent of total water withdrawals – is used in the production of wasted food (Anyabwile and Walker 2019). Given many countries are becoming more drought prone, in

part as a result of climate change, this waste of water could have profound local impacts on human communities (Holden et al. 2015).

Food waste in the UK

WRAP has reported UK food loss and waste statistics for over a decade. WRAP first published estimates of UK household food and drink waste in 2008 (WRAP 2008). WRAP then published two of the most detailed studies on household food and drink waste (WRAP 2014b; WRAP 2014a) that have been completed around the world, as well as one of the most detailed quantifications of hospitality and food service waste (WRAP 2013a). These reports have become global examples of best practice food loss and waste evidence and reporting.

In 2018 the UK wasted around 9.5 Mt of food (post-farm gate), enough to fill St Peter's Square in Rome to the height of the great church's dome. Around 6.4 Mt (almost 70% of the total) was edible and could have been eaten (WRAP 2020a). WRAP also estimates that food surplus & waste in primary production is approximately an additional 3.6 million tonnes a year, or 7.2% of all food harvested (WRAP 2020a). This volume of post-farm gate food waste represents over 25% of total food purchased in the UK, worth US$25bn, nearly 1% of total GDP. As with other wealthy countries, waste in our homes is the single biggest source of food waste across the supply chain. Household food waste makes up 70% of the total UK food waste post-farm gate, at 6.6 Mt. Over two-thirds of this (68%; 4.5 Mt) was food intended to be eaten, with a value of almost £14 billion in 2018 (WRAP 2020a). This represents a cost of £700 per year for an average family with children. The total GHG emissions associated with wasted food and drink in the UK account for approximately 25 Mt CO2e. Additional information on these figures can be found in Table 1. The total cumulative value of the food no longer wasted in the UK is estimated at around £38 billion.

Household food insecurity is also an issue in the UK, with 10% of adults living in households classified as marginally food insecure, and 10% reported living in households with moderate or severe food insecurity (2020b). WRAP has supported food rescue and redistribution operations in the retail, manufacturing and the hospitality & food service sectors to alleviate food insecurity (2019). As result of a combined effort of businesses and charities, the amount of food redistributed doubled (96% increase) between 2015 and 2018. The value of the food redistributed was £166 million (2018). This was enough food to make the equivalent of 133 million meals. In 2019 WRAP opened a £4m Food Waste Fund to further substantially cut food waste and encourage more redistribution efforts.

a) Summary of UK food waste arisings (kt) for SDG12.3 and Courtauld 2025 baseline years and 2018, and changes over time

	SDG 12.3 baseline (kt)	2015 (kt)	2018 (kt)	Change vs 2015 (kt)	Change vs 2015 (%)	Change vs SDG baseline (kt)	Change vs SDG baseline (%)
Household	8,085	7,050	6,646	-405	-5.7%	-1,440	-17.8%
Supply chain	3,110	2,951	2,880	-71	-2.4%	-230	-7.4%
Retail	*290*	*261*	*277*	*16*	*6.0%*	*-13*	*-4.6%*
Manufacture	*1,900*	*1,668*	*1,505*	*-163*	*-9.8%*	*-395*	*-20.8%*
HaFS*	*920*	*1,022*	*1,098*	*76*	*7.5%*	*178*	*19.3%*
Total	11,195	10,001	9,525	-476	-4.8%	-1,670	-14.9%

b) Summary of UK food waste arisings (per capita – excluding inedible parts) for SDG 12.3 and Courtauld 2025 baseline years and 2018, and changes over time

	SDG 12.3 baseline (kg/yr)	2015 (kg/yr)	2018 (kg/yr)	Change vs 2015 (kg)	Change vs 2015 (%)	Change vs SDG baseline (kg)	Change vs SDG baseline (%)
Household	100.0	76.7	68.5	-8.3	-10.8%	-31.5	-31.5%
Supply chain	32.3	29.4	28.0	-1.4	-4.9%	-4.3	-13.4%
Retail	*4.7*	*4.0*	*4.2*	*0.2*	*3.9%*	*-0.5*	*-10.6%*
Manufacture	*16.9*	*13.8*	*11.6*	*-2.2*	*-15.9%*	*-5.3*	*-31.4%*
HaFS*	*10.7*	*11.6*	*12.2*	*0.6*	*5.3%*	*1.5*	*13.7 %*
Total	132.3	106.1	96.4	-9.7	-9.1%	-35.9	-27.1%

c) Value of UK wasted food (post-farm gate) (£bn; all expressed in 2018 prices)

	SDG 12.3 baseline (£bn)	2015 (£bn)	2018 (£bn)	Change vs 2015 (£bn)	Change vs SDG baseline (£bn)
Household	18.58	15.16	13.80	-1.35	-4.78
Supply chain	5.15	5.10	5.19	0.08	0.03
Retail	*0.92*	*0.82*	*0.87*	*0.05*	*-0.04*
Manufacture	*1.58*	*1.32*	*1.14*	*-0.19*	*-0.44*
HaFS*	*2.66*	*2.96*	*3.18*	*0.22*	*0.51*
Total	23.74	20.26	18.99	-1.27	-4.75

Table 1. Summary of UK food waste arisings (kt, per capita – excluding inedible parts – and £bn) for SDG 12.3 and Courtauld 2025 baseline years and 2018, and changes over time.
*It is important to stress that this is a modelled result for the HaFS sector, based on changes in the number and types of hospitality and food service sites, and the assumption that food waste per site has remained constant since 2011. Currently there is not a data source to enable a UK-level estimate for food waste from this sector to be robustly estimated even though we know that many sites have taken action, see www.guardiansofgrub.com

Food waste in Mexico

In 2019 the World Bank and WRAP, on behalf of the government of Mexico, prepared a Conceptual Framework that compiled the data on food loss and waste in Mexico for the first time, painting a compelling picture of the current situation and creating a framework for action (World Bank Group 2019). It was found that around 20 Mt of food was lost or wasted every year from farm gate to retail in Mexico. In addition, there is an estimated 11 Mt of food waste generated by households. Together, this represents over 35% of total food produced in Mexico, and would be worth $25bn, (~2% of GDP). This food loss and waste is occurring at the same time as 24 million people are food insecure and nine million live in extreme poverty in Mexico.

The contrast between the UK figures is instructive, as the bulk of the food loss and waste is in the supply chain rather than the home. Compared to the UK, financially the scale of the opportunity is a significantly larger share of GDP, as is the scale of the opportunity to help tackle food insecurity. By taking these 2 examples, it suggests that all countries could benefit massively from prioritizing action on food loss and waste, although the main sources of food loss and waste are likely to be more country specific.

WRAP is now working with partners in Mexico to tackle this, with one important focus being on recovering surplus produce to sell or donate to those in need. The steps identified in the World Bank Group Report (2019) can be used as foundational elements to develop a national strategy for Mexico.

Understanding the true cost of food loss and waste

The cost of food waste is often understood by many in industry or households to be related to only the "visible" costs of collection, recycling or disposal of food loss and waste (WRAP 2013a). However, there are other "invisible" expenditure and costs that need to be considered, including purchase of ingredients, labour, processing equipment cost, energy, and water which account for nearly 90% of the total cost of food waste (FAO 2014). In the UK the visible cost of waste management is between £80 to £100 per tonne, depending on industry sector (WRAP 2013a), plus additional costs for landfill taxes and gate fees of £88 to £168 (WRAP 2018). However, WRAP has estimated the total cost of food loss and waste is between £1,600 and £4,000 depending on industry sector and the point in the supply chain it is wasted (WRAP 2013a).

Understanding the true cost of food loss and waste enables us to quantify the immense benefits that food loss and waste reduction action can achieve. For example, WRAP has recently estimated that around 150,000 tonnes of household food waste were avoided in 2015 compared to 2007, as a result of technical changes to products (changes to packaging, labelling, pack size, etc). It is estimated that these technical changes have saved UK families around £400 million a year and that an additional 350,000 tonnes of avoidable household food waste (worth an additional £1 billion annually), could be prevented through further changes to key food items in the UK's shopping aisles (WRAP 2017; WRAP 2019a). These technical changes can be low cost, and due to the immense total cost of food loss and waste can result in large savings.

Further evidence of the capacity for food loss and waste interventions to be cost effective comes from the Champions 12.3 network, who have published multiple sector specific "Business Cases for Reducing Food Loss and Waste" (Champions 12.3 2017b; Champions 12.3 2017c; Champions 12.3 2018). These show that nearly every site that invested in food loss and waste reduction achieved a positive return, with half seeing a 14-fold or greater return on investment.

Methods to reduce food loss and waste

Over the last decade the global community has united to address the issue of food loss and waste. Collectively, we now know more about what is effective and what works. There are multiple types of intervention possible to reduce food loss and waste (Reynolds et al. 2019) and two approaches seem to be particularly effective and can work at scale, specifically:

– Public-Private partnerships (also known as voluntary agreements),
– Citizen Behaviour change campaigns.

Both actions have a wide evidence base of working in OECD countries, and working on shorter time scales to rapidly reduce food loss and waste across the entire food system. However, both actions need to be further adapted and tested in a wider array of countries, with a variety of demographics, cultures, and contexts beyond the current OECD examples.

Public-private partnerships

Public-Private Partnerships (PPPs, also known as voluntary agreements), in the context of food loss and waste, are schemes in which public and private sector organisations make commitments to improve their environmental performance, without the need for legislation or additional regulations.

They cover arrangements such as public voluntary programmes, negotiated agreements or unilateral commitments (Boulding and Devine 2019).

In recent decades PPPs have often been implemented in an attempt to help tackle a wide variety of environmental issues: GHG emissions, unsustainable clothing, plastic waste and food loss and waste. Across the EU for example, a number of PPP have been set up to tackle food loss and waste, either covering a wide variety of sectors and stakeholders across the food chain or focusing on specific sectors.

A world-leading example of a PPP is Courtauld 2. Following on the success of the Courtauld 1 (2005-2009), Courtauld 2 was a PPP administered by WRAP that ran for three years (2010-2012), with 53 signatories (including most of the UK retailers, and major brands and suppliers) in the UK (WRAP 2020b). The main aims of Courtauld 2 were to reduce primary packaging and household food and drink waste. It also included reductions in 1) secondary and tertiary packaging, and supply chain waste, and 2) reducing the carbon impact of packaging. The influence of Courtauld 2 resulted in a 10% reduction in packaging carbon impact, 3.7% reduction in household food and drink waste, and 7.4% less supply chain waste (this represents a total of 1.7 million tonnes of waste). This impact has a monetary value of £3.1 billion and equates to a reduction of 4.8 million tonnes of CO_2e. Courtauld 2 was run in conjunction with the consumer-facing campaign of Love Food Hate Waste, and part of the effectiveness of Courtauld 2 can be attributed to this joint approach. Overall the VA approach has helped the UK to reduce total edible food waste by 27% per capita up to 2018 (WRAP 2020a).

In considering their set up, PPPs support the notion that collective action can be more cost-effective and provide greater impact than that experienced when organisations tackle issues in isolation. PPPs have the potential to offer efficient, flexible, and effective alternatives to traditional regulatory structures (Steelman and Rivera 2006), whilst improving the image of both the regulator and the regulated by signalling the willingness of both sides to engage in a more flexible process of environmental protection (Koehler 2007). It is this beneficial flexibility which was highlighted in the REFRESH project (WRAP 2019b), which suggested PPPs help collaboration between stakeholders and supply chains and highlight the best practice approaches necessary to deliver change.

As new food waste PPPs are set up across the world it is imperative that the global community addresses the most frequent challenges they face, to ensure desired food loss and waste reduction outcomes are realised by

PPPs. Some of the most relevant approaches are:

- Ensuring new PPPs follow core principles and well-described fundamentals for the establishment of successful PPPs – such as the REFRESH blueprint (WRAP 2019b)
- Enlisting government support and ensuring the most appropriate lead organisation is selected
- Ensuring PPPs are adequately resourced to assist signatories in delivering targets and developing new best practice where needed
- Continuously revising the dynamics of the PPPs and understanding the mechanisms necessary to ensure high levels of engagement (subsequently achieving impact),
- Setting ambitious yet realistic goals, and
- Further developing appropriate methods to monitor and evaluate progress.

Citizen behaviour-change campaigns

In higher income countries the household is where the majority of food waste occurs. Across the EU, over 53% of food waste happens at this level (Stenmark et al. 2016). In the UK, even though attitudes towards food waste have improved, research shows that 70% of people in the UK believe they produce low or small amounts of food waste (WRAP 2020c). This lack of perception of the problem and scale of food loss and waste is replicated across OECD countries.

Citizen Behaviour change campaigns represent the combination of multiple public facing components to reduce food waste. A citizen behaviour-change campaign is more than just an awareness raising campaign – campaigns that exclusively provide information and increase awareness about the negative impacts of food waste. WRAP has found awareness raising alone has limited long-term effectiveness in relation to actual food waste reduction; for longer term effectiveness a more complex campaign (ie a citizen behaviour-change campaign) is required. Citizen behaviour-change campaigns 1) aim to influence social norms (social norm campaigns are impactful as they exploit the tendency of individuals to conform to what they perceive those around them do), and 2) increase the skills of citizens around food management and food practices (WRAP 2013b).

Indeed, the literature shows that there are many factors that can influence household food waste, including a range of behavioural and technical interventions and shifts in demographic profiles and economic conditions

(Quested et al. 2013). WRAP developed and has implemented a new strategy for citizen food waste prevention, which includes a refocused Love Food Hate Waste campaign and targeted behaviour change interventions (such as those under the EU-funded TRiFOCAL project (2020c)). In addition, an enhanced programme aims to drive changes in food packaging design and labelling to make it easier for people to buy what they need and make use of what they buy (WRAP/UK Government/Food Standards Agency guidance to industry was published in 2017, and progress in this area was reported in November 2019 (WRAP 2019a)).

To support citizen behaviour-change campaigns effectively, policy makers should deploy additional interventions based on regulation, economic instruments and nudging approaches. These may be best harmonised through the development of a national food strategy, to provide an integrated approach to food loss and waste reduction linking to national health policies, the economic policies, and wider resource efficiency and waste policies. Citizen behaviour-change campaigns and their accompanying interventions need to be monitored and evaluated to gain insights about their effectiveness and allow for adjustments to further improved food loss and waste reduction.

WRAP has been at the forefront of citizen food waste behaviour-change campaigns, developing and launching the Love Food Hate Waste campaign in 2007. The campaign helps raise awareness of the issue of food waste and empowers consumers to waste less food and save money through practical advice, effective tools and helpful tips. The Love Food Hate Waste campaign has resulted in increased consumer awareness of food waste issues and has contributed to 24.2% reductions in household food waste – saving around £4.7 billion worth of food per year (WRAP 2020a). The Love Food Hate Waste campaign is now being used in 8 countries including Australia, New Zealand, Canada, Saudi Arabia and Central Europe. Behaviour-change campaigns on food loss and waste are also being effectively run in the Netherlands (Champions 12.3 2017d) and Germany (Federal Office of Agriculture and Food 2020).

How to scale-up food loss & waste reduction

It is clear that there are approaches to reducing food loss and waste which are effective and drive systemic change. The scale of change is sufficient to suggest that halving food waste and reducing food loss by 2030 is possible (for example, a 27% reduction in food loss and waste across the

supply chain has already been achieved in the UK). The return on investment of the public money invested in these initiatives has been impressive, ranging from 80:1 to over 100:1 (Champions 12.3 2017b). To achieve this though requires:

1) Commitment from Governments around the world to prioritise food loss and waste reduction for economic, social and environmental reasons. For example, food waste reduction has been rated as the third most impactful intervention globally to reduce greenhouse gas emissions. This commitment could be best expressed by including food loss and waste reduction in countries' Nationally Derived Commitments (Hawken 2017).
2) The development and implementation of national food waste strategies focusing on national priorities and tailored to national needs.
3) The adequate funding of these interventions to ensure they deliver. The support of the international community in ensuring adequate funds are available is key.

Also key to the successful deployment of approaches that reduce food waste is localisation. These approaches won't be suitable for every country and for most will require adaptation to local conditions and local supply chains. As such a key challenge for food loss and waste practitioners is building capacity of in-country of local partners, who can then tailor the approaches in country and ensure they are effectively deployed.

Let's unite in the food waste fight

In this paper we have offered two mechanisms for scaling food loss and waste reduction at the regional, national and international levels. In this final section we propose a simple three-point plan for tackling food waste to deliver SDG 12.3 over the next 10 years:

1) *Integrate food loss and waste policies into the strategies of all G20 governments* and as many more as we can.
2) *Accelerate the uptake of public-private partnerships globally* – sharing best practice, and building a network for effective delivery.
3) *Work together on effective and tailored behaviour-change strategies* so that not wasting food is the social norm, and we learn to value food and not waste it. These approaches work.

This is a key priority for all working on food loss and waste reduction, building the coalition of the willing and securing the funding that ena-

bles countries around the world to deliver food loss and waste reduction rapidly and cost-effectively. Tackling climate change requires urgent action and reducing food loss and waste offers an approach that can be deployed rapidly and deliver impact at scale, using tried and tested approaches. The imperative now is to act and act now.

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Towards a Sustainable Global Food Supply and the Cold Chain

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The first of the seventeen Sustainable Development Goals (SDG) of the UN is eliminating poverty. We describe in this chapter the value that the food cold chain (FCC) provides in enabling a sustainable global food supply which can help with this important goal of the UN. The cold chain is the complex network of private and public sector provided infrastructure and products that allows for safe collection, transportation, processing, storage, and display for sale or consumption, various foods, both farm-grown and processed. As the name implies, the food cold chain ensures the freshness and quality of food by maintaining food at the optimum conditions for safety and quality. The private industry and the Global Food Cold Chain Council have come together, in partnership with UNEP and other groups, to map the current state of the FCC by launching an effort to create a database and the modelling of scenarios for expanded global food cold chains, its carbon footprint (GHG emissions), energy consumption, refrigerant transition and reduction of food losses. This chapter follows much of the information to be presented in the paper at the International Institute of Refrigeration (IIR) International Conference on Sustainability and the Cold Chain (ICCC) in Nantes, France on April 15-17, 2020.

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1. Introduction

Studies show a clear trend to a rapid increase in global cooling demand over the coming decades, especially in developing countries where roughly 40 percent of the global population lives (expected to climb to 50 percent by 2030*),[7] and where the need for cooling is most crucial. Even in moderate climates, it would be impossible to support a modern urban economy without adequate cooling. Demand for cooling will increase even more in developing countries because of expected global warming, population growth and massive growth of urbanization.

While the benefits of cooling are unquestionable, there is widespread concern that its development may generate undesired consequences such as greater emissions of Green House Gases (GHG), directly from the leaks of refrigerants (commonly used for refrigeration in the FCC) to the atmosphere, and indirectly though the associated energy consumption. These concerns are being addressed by international agreements, especially the Montreal Protocol and its Kigali Amendment, and the Paris Climate Agreement; but many questions remain about implementing these agreements. Other concerns are the infrastructure required for generation and distribution of energy, need for qualified labor, appropriate refrigerant management, and more.

The two major sectors where cooling is needed are "comfort cooling" or air conditioning (A/C), and Food Cold Chain (FCC). Other applications also exist, like industrial (chemical, pharmaceutical) cooling, data center cooling etc. Over the past years, there has been significant focus on the A/C sector; the current markets and anticipated needs are relatively well identified, as well as possible road maps achieving the desired solutions. But the FCC sector is not nearly as well analyzed. It is also closely interlinked with critical issues related to nutrition, like food production and waste, land use, cultural behaviors toward food etc. Therefore, there is an urgent need to develop a map of the current state of FCC, perspectives of development, and possible consequences.

2. Scope of FCC, technologies and challenges

2.1. Scope

In general, FCC encompasses all the cooling required for food production, processing, storing and distribution "from farm to fork". There are sev-

[7] Source: http://worldpopulationreview.com/countries/tropical-countries/

en major sectors of applications: primary production (fishing and farming), processing and packaging (dairy, meat, and produce…), bulk storage, transport, retail (shops and vending machines), food service (restaurants, catering), and domestic refrigeration. The medical sector (hospitals, tertiary, transport and storage of pharmaceuticals) is also included in some of the studies.

2.2. Technologies

A predominant amount of equipment that provides cooling in the FCC uses what is known as "vapor compression" method, which relies on a fluid called a "refrigerant" as the working medium for the movement of heat. Most of the cooling needs for FCC are at two typical temperature levels: around 0 to 5°C for processing and storage of fresh produce, or around -20°C for frozen products. A few applications such as dry freezing or high-quality freezing require substantially lower temperatures, as low as -60°C.

Cooling capacities range from a few hundred watts for small household refrigerators to several megawatts for large warehouses of food processing plants. Small systems like home fridges or small vending machines are self-contained hermetic systems. Large systems are usually "flooded", using liquid refrigerant pumped to various applications from a central machine room. Intermediate systems are based on condensing units feeding refrigerants to a few "dry-expansion" cooling coils at various points of use.

In medium and large refrigeration systems, the hydrochlorofluorocarbon (HCFC) refrigerant R-22 was widely preferred, with ammonia (R-717) as the choice for industrial systems. R-22, which is in the process of being phased out under the Montreal Protocol, has been mostly replaced by higher Global Warming Potential (GWP) hydrofluorocarbons (HFC) refrigerants R-134a and R-404A in developed countries. Solutions generally exist to replace R-404A and R-134a with lower GWP fluids in new and existing systems, except for the retrofit of large flooded R-22 systems. There are also satisfactory solutions for small self-contained systems. A detailed review of the various sectors, technologies and trends can be found in the series of "Cold Chain Technology Briefs" published by the IIR and UNEP.[8]

[8] https://iifiir.org/en/fridoc/142038

3. FCC contributions to achieving the SDGs

The Sustainable Development Goals (SDGs) were established by the UN in 2015 for achievement by 2030, as part of the 2030 Agenda for Sustainable Development. They consist of 17 goals aimed at improving livelihoods and achieving sustainable development with regards to environmental, social, and economic global equity. The 17 goals (and associated targets) cover areas of concern such as poverty and poor health conditions, as well as implementation groundwork like partnerships and financing. The development of cooling is strategic to achieving many of these goals; for instance:

	**Reduced food loss and food waste.** A robust cold chain can significantly reduce the loss of food caused by spoilage between food production and food retail. In developing countries, more widespread use of residential refrigeration can significantly reduce food waste at the point of use. Current levels of food loss and waste are estimated to be around 30% of all food produced. This creates significant GHG emissions which can be avoided by improving the food cold chain.
	**Improved healthcare.** Around 50% of medicines are heat sensitive and require a robust cold chain to avoid wastage and dangerous degradation of products. Many types of sophisticated medical equipment (such as scanners) require cooling, and cooling is crucial for blood and tissue storage.
	**Affordable and clean energy.** The increased use of renewable energy sources comes with challenges to balance electricity supply and demand. Cooling, as well as heating by heat pumps, can provide solutions to optimize the balance, for example by demand shifting controls as well as storing energy (cold and hot storage, also called "thermal" storage batteries).
	Addressing undesired consequences of cooling through the use of sustainable cooling aligns with the important SDGs related to **climate action** and **responsible consumption and production**. A sustainable cooling approach also implies making responsible use of natural resources to produce cooling equipment (for example copper, aluminium, steel, refrigerants). This includes the need to reduce, recover and reuse these materials, contributing to a circular economy approach.

4. Intergovernmental framework

4.1. Kigali Amendment and Paris Climate Agreement

Countries ratifying the Kigali Amendment and (or) the Paris Climate Agreement accept the obligation to take actions at multiple levels. Regarding refrigerant fluids, the phase out of HCFCs (including R-22) is nearly completed in "Article-2" countries (basically developed countries, accord-

ing to the Montreal Protocol terminology), but is still ongoing in "Article-5" (developing) countries, implementing their HCFC Phase-Down Management Plans (HPMP). But there is now an additional level of complexity with the need to combine it with the phase-down of HFCs. This phase-down is already under way in the EU under its F-Gas Regulation; it is starting in other Article-2 countries under the Kigali Amendment, and will have to be taken into account in Article-5 countries soon as well.

Wider objectives of GHG emissions also have to be worked out by countries that ratified the Paris Climate Agreement, according to their Nationally Determined Contributions (NDC). In any case, limiting energy consumption is a must everywhere for many reasons, including the critical need to reduce air pollution in many cities.

So, countries ratifying the Kigali Amendment and the Paris Climate Agreement have to implement their HPMPs, comply with HFC phase-down per Kigali Amendment, and work out their Nationally Determined Contributions (NDC) under the Paris Climate Agreement, all these targets being interlinked. Even the countries that did not ratify the Kigali Amendment and (or) Paris Climate Agreement will be strongly impacted by the same trends. For this reason, some countries like China, India and Rwanda have already developed national Cooling Action Plans (CAP), while many others are working on it. Irrespective of legal obligations, such plans are needed everywhere to address the many challenges raised by the needed development of cooling.

4.2. Technologies

In addition to the aforementioned international agreements, action is also driven by some resolutions of the UN Environment Assembly (UNEA) regarding Food Loss and Waste. UNEA is the governing body of UNEP and has universal membership of all 193 states; it meets every two years to set international priorities for global environmental policy and law.

UNEA Resolution 9 (2016) recognizes that national governments and international institutions play a central role in contributing to solving global food loss and waste problems. Organizations should:

a) Promote market-based incentives, co-operation with stakeholders in cold chain sustainability, and improve measurement of food loss and waste.
b) Implement programs that reduce food wastage and reuse of edible food that might otherwise be wasted.

UNEA Resolution 9 (2019) states that organizations and institutions should:

a) Contribute towards solving food loss and waste with an orientation

towards addressing environmental, socio-economic, and public-health problems.

b) Engage with stakeholders in food systems and participate in international efforts.

5. Sustainability of the FCC: A paradox?

While there is no doubt about the benefits of cooling in general and more specifically of the FCC, some concerns are being raised that its expansion could have undesired environmental consequences through emissions of refrigerant fluids and increased energy consumption. But this must be put in perspective with the substantial benefits of the FCC also from an environmental standpoint. Studies show that nearly 30% of global food production is lost or wasted, while the production of this lost or wasted food itself also has a large carbon footprint.

If food loss and waste were a country, it would be considered the third largest GHG emitter (Figure 1). Therefore, all efforts to minimize food loss and waste will positively and notably contribute to Climate Actions. As a substantial part of food loss is due to the lack of refrigeration, expanding the FCC will indirectly reduce GHG emissions from food loss. Only 20% of perishable foods produced worldwide are actually refrigerated (Source: IIR, 2019).

A study made by Deloitte (source: Global Food Cold Chain Council, 2015) shows that the emission benefits of introducing cold chain technol-

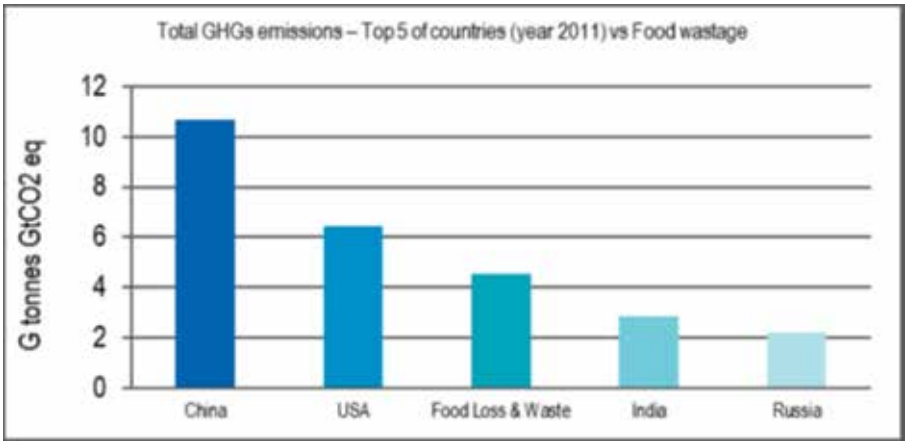

Figure 1. Food and Agriculture Organization of the United Nations

ogies from farm to market are almost a factor of 10. We still need to investigate the impact of modern retail and home appliances in a full modern cold chain, and this will add some emissions. However, low GWP refrigerants, energy efficiency and energy management to serve decarbonized electricity grids will minimize this impact.

Several scenarios must be outlined based on a Business As Usual (BAU) scenario as a reference in a model of the FCC development. Without globally acknowledged models and executed plans food cold chains will develop autonomously and likely be far from sustainable.

6. Need for the FCC mapping

In order to identify how the FCC can better serve the goals of sustainable growth in food availability, various approaches are possible. One approach is to start from statistics about the production, imports and exports of agricultural products in various countries. It is a good starting point, as the FAO (Food and Agriculture Organization of the United Nations) has robust statistics on this data; but it is not enough: while almost two thirds of global food loss is estimated to be caused by a lack of refrigeration in the cold chain, more work is needed in areas such as:

- Using a holistic and overarching sectors approach
- More data on understanding the economic and social reasons
- More data on industrial, environmental and cultural factors

6.1. Different initiatives and groups addressing the subject

GFCCC

The GFCCC (Global Food Cold Chain Council) is a coalition of private sector companies involved in global food supply technologies. The GFCCC aims to reduce emissions and food wastage in the food cold chain by expanding and improving energy efficient, low GWP infrastructure and technologies. This is achieved through research, outreach, and implementation of projects.

UNEP

UN Environment is the leading global authority on environmental issues and sustainability. UNEP partners with a range of actors to create and implement sustainable development and environmental strategies. UNEP is leader in Champions 12.3 and has established a number of initiatives and projects.

FAO

FAO is the UN agency specialized on its central objectives of achieving food security and eliminating hunger and malnutrition. It works with governments and international organizations to promote awareness and develop policies; facilitate coordination amongst food supply chain actors; and educate consumers on safe food handling, food storage, and identifying spoiled foods to prevent food waste.

Champions 12.3

Champions 12.3 is a coalition of bottom-up and top-down experts and commercial groups committed to addressing SDG 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". The Coalition does this through a range of projects that include knowledge and best practices information sharing, publicizing food wastage and promoting sustainability, identification of opportunities that enhance and encourage food sustainability.

IEA

IEA (International Energy Agency) promotes energy sustainability through analysis of all energy sources, energy efficiency, supply and demand, technologies, markets, and demand side management. It partners with countries and organizations to support economic development, environmental awareness, and energy security.

IIR

IIR (International Institute of Refrigeration) is an independent inter-governmental organization that promotes knowledge on cost-effectiveness and environmental sustainability in refrigeration and associated technologies.

7. The cold chain database model project

7.1. Purpose of the project

To address the aforementioned issues, UN Environment and GFCCC have jointly initiated a project for the development of a complete database for the modelling of Food Cold Chains. The expected benefit for the various countries is to have suitable data available to fulfill their obligations under the Kigali Amendment and the Paris Climate Agreement, and also

to prepare relevant national policies about cooling, energy, infrastructure etc. To do this, the initial and longer-term objectives are:

Initial: understand current status, with assessment of stock of cooling equipment in different sectors of the FCC, energy usage and related CO_2 emissions, refrigerants usage and related CO_2 emissions, levels of food loss linked to the lack of FCC.

Long-term: assess future scenarios with different levels of improvements to the FCC, with assessment of investments required, potential benefits (e.g. GHG reduction, financial value of food saved), and potential impacts (e.g. additional use of energy and refrigerants, CO_2 emissions); finance will also be a major issue to deploy solutions; it will be crucial to have a robust analysis to define suitable solutions, and also to build confidence in investors that the solutions are reasonable and optimized.

7.2. Data collection

A key part of the project will be data collection, beginning with background research, using international data sources such as FAO statistics and the wealth of data and previous studies already conducted by the IIR. Then, more detailed analyses will be conducted at national levels. "Stage 1" will report about national data sources and results from dedicated questionnaires to be documented by the countries. This will include the collection of available statistics on production, number of relevant FCC facilities, level of food loss etc. In "Stage 2" more detailed data will be gathered, based on customized investigation plans and detailed data from this plan.

This data collection will first be conducted in five or six pilot countries, then extended to others after validation of the methodology. Relevant local contacts will be made initially through the National Ozone Officers of the countries, but will also involve the local networks of the various organizations involved in the project, such as the commercial networks of the companies participating in GFCCC, the IIR networks, trade associations, and other intergovernmental organizations, which will also contribute with their technical expertise.

All data collected by the countries during the pilot stage, and shared with partners in the cold chain model for review and analysis, will be dealt with in a confidential manner and shall not be shared without consent of the respective country.

8. Importance of private sector involvement

A key feature of this project is the impact of the private sector and is very important at various levels. Industry partners were involved at earlier

stages to set the structure of the model by market sectors and sub-sectors, jointly with other experts like from IIR. This expertise will also be important to analyze the results, draw some conclusions, envision scenarios for the future and anticipate implementation.

The refrigerant transition has to be addressed as well. Some of the currently used technologies could be "leap-frogged" to lower GWP technologies where feasible, particularly in developing country economies. But refrigerant issues are only a small part of the puzzle, wherein energy and costs are the key issues. Just making a "copy-paste" of solutions currently used in developed countries would not be satisfactory. Energy use must be reduced both in developed and developing countries, with an adequate mix of using currently existing "BATs", and innovation. Current Best Available Technologies (BAT) must be deployed because the systems to be installed in the forthcoming ten years or so are bound to be among solutions that are already commercially available today, or at an advanced stage of development; but less efficient solutions would result in unacceptably high-energy consumptions. Simultaneously, innovation is needed to develop more energy efficient solutions for the future. Yet, there are limits to the efficiency of thermodynamic machines. Besides improving them, most of the improvements are expected to come from the reduction and management of cooling loads, e.g. by better building envelopes, and by better integration of systems to serve a decarbonised electricity supply. This will require close scrutiny of local needs and current practices, for which the "database" is expected to be a useful tool. The involvement of industry at this early stage is also expected to benefit the development of reasonable road maps".

9. What policy forum is best for dealing with food loss and waste?

The question arises where is the best policy forum in which to deal with the challenges and opportunities presented by the issue of food loss and waste. The issues are definitely cross-cutting, dealing with multiple disciplines and government departments, and not necessarily having a singular policy focus. Traditionally, agriculture issues have dealt with increasing production and trade, and avoiding crop damage due to weather, pestilence and disease. These have traditionally involved National Departments of Agriculture and Trade. Given the growing impacts of food loss and waste, and the myriad of areas in which climate-related issues are now dealt, it would be helpful to find a forum in which activities could coalesce. Research has shown that the issues are now being examined and dealt with in Agriculture, Environment, Economic Development, Food Loss and Waste, and Foreign Ministries.

At its last Meeting of the Parties, the parties to the Montreal Protocol issued the Rome Declaration on the Contribution of the Montreal Protocol to Food Loss Reduction through Sustainable Cold Chain Development, which calls upon the Parties to strengthen and coordinate "Between Governments, the institutions of the Montreal Protocol, the specialized agencies of the United Nations, existing private and public initiatives and all relevant stakeholders to exchange knowledge and promote innovation of energy-efficient solutions and technologies that reduce the use of substances controlled by the Montreal Protocol in the development of the cold chain, thereby contributing to the reduction of food loss and waste". The declaration has been signed by 78 parties and the European Union, and more are expected to follow.

The Montreal Protocol has a 30-year track record of success in environmental protection, distribution of financial assistance, achieving significant technology transitions on a global scale, and developing major focal points for policy development.

Success in reducing food loss and waste need not be viewed as a regulatory challenge, but rather an economic opportunity that also provides real environmental and societal benefits. As was pointed out earlier, reducing food loss and waste touches on many of the UN's Sustainable Development Goals.

UN Environment has also created its initiative for the Climate and Clean Air Coalition (CCAC), whose mission is to promote significant greenhouse gas reductions while also capturing related environment and health benefits. CCAC has had an active initiative on HFC emissions reduction, and has also established a goal of developing a program on food loss and waste.

It would appear that an opportunity to link the Montreal Protocol with CCAC and the Food and Agriculture Organization (FAO) may provide a good focal point for achieving real long-term reductions in food loss and waste, relevant sustainable cold chain technology expansion, and providing an experienced record for scientific, technology, and economic assessment. This is just one example, but it would succeed in developing the multi-disciplinary approach necessary to achieve the economic and environmental opportunities that are possible. Other venues may also be appropriate. It is critical that policy leaders look for this multi-disciplinary forum and policy opportunity in the near future.

10. Conclusions

The development of cooling in general and the FCC in particular will be critical for human wellbeing and to achieve many of the SDGs in the forthcoming decades, but it has to be planned carefully to avoid undesired consequences, especially from an environmental standpoint. The FCC had drawn little attention from policy makers until recently, but it is now quickly gaining visibility. Several initiatives have been started to design suitable roadmaps. One of the key initiatives was presented, with joint efforts from UNEP and GFCCC, to make a fact-based analysis of this sector, jointly with other organizations like FAO, IEA or IIR. A key feature of this project is that it directly involves policy makers and industry. It is hoped that this initiative will enable the successful development of a sustainable FCC, including solutions optimized for various contexts, and facilitating financing for the deployment of suitable solutions. An appropriate multi-disciplinary forum is necessary in order to move the policy process and to capture the environmental and economic opportunities.

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Waste Not, Want Not. How Science-Based Solutions Can Help Feed the Ten Billion

Jacobine Das Gupta[1]

For much of recorded history, the struggle to eat was the main focus of human activity; food was a scarce and precious good – and regarded as one too. Today, the picture is somewhat different, with marked imbalances from country to country. While more than 820 million people worldwide suffer from hunger, a third of the world's produced food is lost or wasted before consumption – the equivalent of 1.3 billion tons per year, with a monetary value of USD$936 billion.

Indeed, the costs of food wastage are paid by society as a whole – it is a threat to food security, the economy and the environment. Did you know, for example, that if food waste were a country, it would be the third-largest generator of greenhouse gas emissions, after China and the United States? That the amount of food loss and waste is enough to alleviate one-eighth of the world's population from undernourishment? And that 25% of the world's fresh water supply is used to grow food that is never eaten?

But the fact that food loss and waste are intersectional issues also provides hope for positive change: as the EAT-Lancet report (2019) suggests, "*food is the single strongest lever to optimize human health and environmental sustainability on Earth*". Specifically, halving our food loss and waste, according to the report, is one way we can meet the need to feed almost ten billion people by 2050 within the planet's boundaries, and drive toward meeting the UN's Sustainable Development Goals (SDGs) – a fact that brings new significance to the old phrase "*waste not, want not*".

Sustainable, science-based solutions

Achieving such a significant reduction, however, will require a carefully considered and coordinated approach. With food loss and waste taking place at many stages in the value chain, from the farm to the consumer, a range of stakeholders – including farmers, transport and storage specialists, food

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producers, nutritionists, retailers as well as economists, consumer behavior specialists, and policy makers – all have a role to play in tackling the issue. After all, only an intersectional response can tackle an intersectional issue.

Science will also no doubt have a key role to play in tackling food loss and waste. Around the world, science-based solutions are helping to safeguard our current and future natural resources, as well as unlocking more value from these resources. By driving scientific progress, we are collectively allowing ourselves the best chance to tackle food loss and waste efficiently and effectively, and overcome important technical challenges in production, transportation, delivery and storage.

At Royal DSM, our history of developing sustainable, science-based solutions, together with our partners, positions us particularly well to address technical challenges facing the food value chain. Food waste is relevant to all of our organization's focus areas: nutrition and health, climate and energy, and resources and circularity. Indeed, several of our solutions already address food loss and waste. What's more, our range of solutions can address food loss and waste at different parts of the food value chain, tackling multiple causes.

DSM's initiatives to address food loss and waste follow three pillars: (1) improve (2) enable and (3) advocate. We take action to reduce food waste at our own sites; we deliver solutions that enable producers, manufacturers, and consumers across the value chain to reduce their food loss and waste; and we work with organizations to advocate for wider action on food loss and waste and for accurate metrics to measure it. In this way, we ensure our impact reaches as far as possible.

Setting the right example

Sustainability starts at home – our efforts to enable and advocate for reduced food loss and waste mean nothing if we do not 'walk the talk'. Accordingly, at DSM, we strive to reduce food waste at our sites, where our canteens feed about 23,000 employees. This involves understanding the existing level of food waste and our contractors' strategies to address it. Many already have food waste reduction strategies in place – for instance, at sites in the Netherlands, our caterers make soups from vegetables that would otherwise be wasted.

As a further step, we have started to measure and reduce plate waste. For example, in collaboration with caterer Sodexo, we have been able to reduce food waste at our China sites by 25%, through an initiative to encourage clearing plates. Under a similar initiative at our Prato Limpo site

in Brazil, employees who clear their plates are given stickers, which can be traded for rewards such as coffees. These efforts have even extended beyond the canteen: at our site in Delft, the Netherlands, employees have created a cookbook with recipes aimed at using up leftover food, which are distributed to all employees at the site. This helps to make the topic 'come alive' not only in one's kitchen at home, but also as a source of inspiration: How can we as DSM apply our biotechnology, human and animal nutrition science to identify losses and come up with new innovations for preventing losses or repurposing leftovers?

Enabling change throughout the value chain

Beyond improving our own impact on food waste, DSM aims to develop and deliver science-based solutions that enable other players throughout the value chain to reduce food loss and waste – from farm to fork. Our solutions are particularly well placed to reduce the loss and waste of milk, poultry, and eggs, important contributors to food loss and waste, and to address the specific issues each part of the value chain faces.

Avoiding broken eggs

For example, when it comes to animal proteins, poor animal nutrition can result in food losses or unusable products such as broken eggs. As such, animal nutrition solutions, although applied at the pre-farming stage, play an important role in reducing this kind of food loss. In particular, an active form of vitamin D3 (Hy-D®) improves chicks' skeletal health and development (Figure 1). In layers, it improves eggshell strength, resulting in a significant reduction in egg breakage – in fact, trials confirmed it can re-

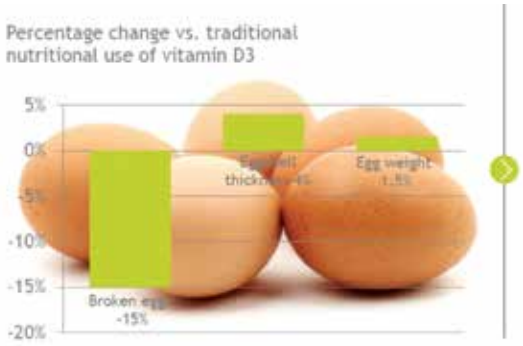

Figure 1. DSM.

duce egg loss by 15%. Besides strengthening the eggshells, the feed additive improves animal welfare and can help reduce antibiotic use.

Preventing cheese-ripening losses

Food loss also occurs during processing and manufacturing of dairy products such as cheese. For example, conventional solutions for ripening hard and semi-hard cheeses typically lead to the formation of an inedible crust. Our Pack-Age® cheese-ripening solution reduces some of this food loss. Its moisture-permeable, breathable membrane naturally protects against mold and yeast growth during ripening. It further eliminates crust formation, producing a higher yield of safe and edible cheese, and reducing cut-off waste up to 7%. In fact, if all naturally ripened gouda and parmesan cheeses were ripened with Pack-Age®, 3.6 billion liters less milk would be needed to produce the same amount of cheese and about 200,000 tons less cheese would be wasted. That is the equivalent to milk produced by 400,000 cows, or the equivalent of a production of 6.25 million metric tons of CO_2 every year.

Extending shelf life

As food reaches the supermarket, one of the biggest challenges in reducing waste is improving shelf life, preventing food and beverages that have been produced and transported all the way to the supermarket from ending up in the bin. Here, several solutions can play a role.

First, our Akulon® plastic wrap enables food to stay safe and fresh for longer. Akulon® uses high-performance polyamide 6 materials to protect food – from meat to rice – from spoilage, aging, and discoloration. Its high puncture resistance reduces damage to food during transportation, and its semi-crystalline structure provides a strong barrier against oxygen and aromas, prolonging shelf life. This protects food safety and quality and helps maintain the nutritional value of packaged food, reducing the likelihood that supermarkets will have to throw it away. Another solution that prevents food from being thrown away too early, is the use of vitamins in animal feed, that prevents meat from being discarded due to discoloration, which is a common consequence of oxidation. By using vitamin ingredients in animal feed, the oxidation of meat is slowed down and the color preserved, which results in extending the shelf life of fresh meat by up to 6 days. Lastly, shelf life is important not only during production, distribution and in retail, but also once products reach the consumer. Longer-lasting products enable consumers to keep them for longer, re-

ducing food waste. Our biopreservatives and antioxidants such as Qual-i®-C Vitamin C are further solutions that can help. Vitamin C slows down the oxidation process, both prolonging shelf life and providing nutritional benefits – a scientifically proven way to reduce food waste. Not only that, but keeping products for longer also allows consumers to save money.

What gets measured get managed

Nevertheless, implementing these solutions can sometimes be a challenge. While our solutions are good for profit as well as for the planet, the economic benefits are sometimes received not by the part of the value chain that implements a solution but elsewhere, making it difficult to incentivize farmers and manufacturers to adopt them. For this reason, collaboration and advocacy are an important part of our efforts to reduce food loss and waste. By advocating for the importance of conserving food, we can create market environments in which our solutions can be widely implemented, and therefore have maximum impact.

Advocating for more consistent metrics for measuring food loss and waste is also an important part of these efforts (Figure 2). In particular, some definitions of food loss take pre-harvest losses into account, while others do not. This can significantly affect whether pre-harvest-stage solutions such as our animal nutrition solutions are fully recognized, despite their important role in reducing food loss. To address issues such as these and learn from our peers, we are involved in initiatives and partnerships that advocate together for greater food conservation, such as Champions

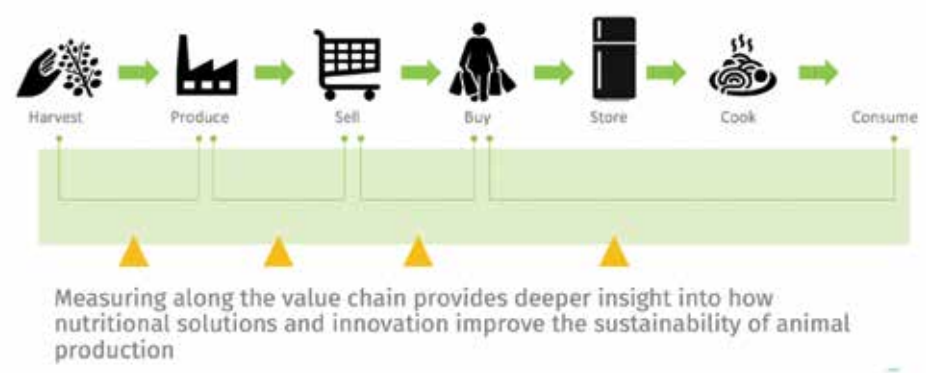

Figure 2. DSM.

12.3, the World Business Council for Sustainable Development (WBCSD) FReSH program, the WEF, WRI, WWF, and Food Drink Europe.

Advocating for value chain cooperation

DSM long-serving CEO Feike Sijbesma first signed up to Champions 12.3 for several years. This coalition of executives from governments, businesses, international organizations, research institutions, farmer groups, and civil society works toward achieving Sustainable Development Goal 12.3 by 2030 by advocating for reduced food loss and waste. In this role, we report on food loss and waste and act as ambassadors for reducing it, by raising awareness of different technological solutions, publicizing the successes of these solutions, and leveraging the necessary relationships to finance them, as well as other strategies aimed at meeting SDG 12.3.

Additionally, as part of the WBCSD FReSH program we work to provide sustainable, healthy diets for all, of which an important part is reducing food loss and waste. The WBCSD FLAW working group, in particular, aims to align on definitions of food waste, support the implementation of an 'FLAW Value' calculator to translate the amount food lost or wasted into avoidable greenhouse gases, land use or water equivalents, thereby presenting food loss and waste reduction also as a climate solution, and provide leadership on food loss reduction. In this way, we aim to make measuring and reducing food loss and waste as understandable, attractive and easy as possible.

Everyone to play a role

Through our various efforts, we're maximizing the impact we can have on reducing food loss and waste and setting an example for other businesses. But we cannot achieve the necessary levels of loss and waste reduction alone. Since food loss and waste have multiple causes across the value chain, businesses from across different industries must collaborate to address them. Specifically, the WRI recommends '10-20-30' supply chain initiatives as one way to tackle food loss and waste, where a country's largest ten food manufacturers and largest 20 suppliers cooperate toward halving food waste by 2030.

NGOs, governments, and citizens also have a role to play in ensuring businesses' solutions are widely implemented. For instance, governments can subsidize research and development on food loss and waste reduction, enable greater transparency in food value chains, and invest in programs to encourage consumer behavior change. National climate action plans

can also incorporate recommendations and solutions for reducing food loss and waste, and track progress toward meeting these targets. Retailers have a role to play by using 'best before or also good after' data labels, and by not refusing or discarding the 'ugly' fruits and vegetables but by selling them as another category. Citizens in turn can make a huge difference through better purchasing planning and by consciously buying appropriate portions. These all help prevent foods ending up in the back of the fridge and later in the bin.

Join us to reduce food loss and waste

Above all, we must collaborate closely to reduce food loss and waste by developing solutions and ensuring they are successful. This can only be done as a collaborative effort, by changing the system, together. If your organization shares these goals and would like to partner with us on initiatives to reduce food loss and waste, we invite you to come on board and join forces. Together, we can feed the soon-to-be ten billion. Tackling food loss and waste is an important means to helping to 'create brighter lives for all'.

VI: ADDRESSING RELIGIOUS AND MORAL ISSUES OF FOOD LOSS AND WASTE

Addressing the Religious and Moral Issues of Food Loss and Waste

Marcelo Sánchez Sorondo

Thanks to globalization and to the interfaith and ecumenical dialogue promoted by the Second Vatican Council, the various religions know one other better.

On the basis of this new mutual knowledge, religions today are called to act together to promote and defend the human dignity of each person and their body, as well as the planet.

The loss and waste of food affects both climate change and people's lives and bodies.

While the Second Vatican Council fostered a dialogue strictly around the religious theme, that is to say what united us and differentiated us in relation to the notion of God, the Pope today wants us to walk and act together to promote and defend human beings and their habitats, as well as the loss and waste of their food.

In order to accentuate this novelty, the recent Synod of the Amazon proposed the idea of a sin against nature or against God the creator. A sin is committed against nature when it is abused. A sin is committed against nature, against human beings and against God the creator, when food is lost or wasted.

In the Lord's Prayer, the model of every Christian prayer, we ask God to give us our daily bread. Bread is a symbol of all food or energy we need to survive and live well and happily.

Asking God for our daily bread means that we are willing to do everything in our power to have that bread. Just as when I ask God for peace, I am supposed to do everything in my power to obtain peace, so when I ask God for daily bread, I am supposed to do everything in my power to obtain such bread.

And I ask God not only for everyday bread for myself, but I ask for daily bread for all: "Our Father… give us our daily bread". Therefore, this requires me to take responsibility to do everything in my hands not only for me to have my daily bread but for all of us to have our daily bread.

Such a requirement implies a new or renewed moral imperative to do everything in my power so that I and all the members of the human family have daily bread.

Now for everyone to have our daily bread it is necessary to produce enough food for the whole human family, taking into account the situation of the planet due to climate change, that is to say, to produce food not only without damaging the sources of nature but by sustainably developing such production, or according to bioeconomic criteria.

Secondly, it is necessary that food is not lost or wasted throughout the entire production and distribution chain.

In brief, religions and faiths need to act together to produce and distribute enough food for the entire population of the world, based on the criteria of sustainable development and bioeconomic criteria, without damaging the planet or losing or wasting any resources.

Food Waste – Some Ethical Reflections

Mickey Gjerris[1]

Introduction

Humanity faces a number of very serious and interconnected crises, as visible in the United Nation's 17 Sustainable Development Goals (United Nations, 2020). Many of the goals are directly or indirectly connected to food waste and food loss, most obviously Goal No. 2: Zero hunger. But the goals: eradicate poverty (1), clean water (6), responsible production and consumption (12), climate action (13), life below water (14) and life on land (15) also carry implications for current food production practices and consumption patterns. A growing world population, climate change, pollution from food production, scarcity of vital resources such as water and agricultural land and the rapid loss of biodiversity that by some has been characterized as the "sixth mass extinction" (Ceballos et al., 2015) necessitates that global food production and consumption undergo rapid and extensive transformation. Part and parcel of this is reducing food waste and loss.

This can hardly be said to be a controversial statement. Further, neither is it a controversial statement to say that the abovementioned issues are not only a question of developing technological solutions or new ways of "food governance". Both are obviously necessary to achieve a rapid and extensive global transformation of food production and consumption. However, underneath these issues lie ethical issues concerning who has the responsibility to initiate the transformation and not least whether food waste and loss is "only" a problem in terms of negative effects for humans, or if food waste and loss is a symptom of a deeper crisis between humanity and the rest of the natural world.

Food waste and loss – a complex and contested concept

Initially the issue of food waste and loss seems very easy. The obvious thing to say, when confronted with the issue, is: "Let's stop doing that". Things are, however, rarely that simple. For one, food waste and loss happens in all links of the chain from primary production to end-consumer

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and there are very different reasons for it, depending not only on what link it is, but also on local socio-economic structures. Discussing food loss and waste as such is therefore much too general an approach to take (Bagherzadeh et al. 2014). Solutions to food loss from small farms in developing economies due to lack of infrastructure are obviously very different than solutions to food loss from intensive production systems in developed economies due to standardization of e.g. processing machinery, just as food waste in households in developing economies due to lack of electricity must be handled differently than food waste in households in developed economies due to lack of knowledge about how to utilize foodstuff.

A further problem is that there is no clear and agreed upon definition on what constitutes food loss and waste, which creates problems when comparing data from different regions etc. Further, it complicates things when estimates of food waste and loss differ, as the difference in estimates can also create a difference in both the understanding of the severity of the problem and subsequently the resources spent on preventing it. One of the reasons that it is difficult to agree upon a definition is that all definitions carry with them certain cultural norms of what is considered "loss" and "waste". What is considered waste in some countries may not be considered waste in others, e.g. internal organs of some animals (Gjerris & Gaiani 2013).

Indirect avoidable food waste

As mentioned above, the disagreement around food waste definitions is not merely a technical discussion but reflects both underlying cultural and social assumptions and ethical values. An example of a food choice which, to some, involves food waste and loss, whereas to others is an acceptable use of resources is feeding animals with plants that could have been used for human consumption.

This is an example of "indirect avoidable food waste": the use of resources in an inefficient manner. Thus, animal products in general can be said to constitute food waste unless they have been produced in such a way as to only utilize resources (land, water, energy etc.) that could not have been used more efficiently in producing plants with the same nutritional value.

Obviously, this goes against many cultural traditions and socially embedded practices. Animal products are seen by the vast majority of western consumers as a normal part of their diets and the environmental impact of e.g. feed production as a necessary part of production. But seen from a resource efficiency perspective one might ask, in the light of the severe

crisis threatening us, whether (at least some) animal products should not be counted as food waste or loss. How one thinks on this issue is not only related to food waste, but also to other values concerning the human-non-human animal relationship and thus, to some degree, by where one finds oneself in the spectrum from carnism to veganism.

Food waste and "the good life"

Another issue is the way that food waste, to some extent, can be seen as an expression of "the good life". According to the report "Food Waste Prevention in Denmark", Danish households are responsible for around 260,000 tonnes of avoidable food waste each year (understood as "food and drink items which, at some point, prior to being thrown out, were edible"), which constitutes 36% of the total food waste in Denmark of 715,000 tonnes per year (Tonini et al. 2017).

There are many reasons behind this food waste as shown in Stancu & Lähteenmäki (2018), poor planning and lack of kitchen skills being some of them. When asked what could motivate to diminish food waste, Danish consumers mention economy as the most important, but also that it could save time from shopping to food preparation, lessen their environmental impact and give them a more "orderly" kitchen.

It is, however, worth noting that the typical Danish household spends only approximately 10% of their available income on food, meaning that food is relatively cheap in Denmark when compared with overall income. Not wasting food might be harder to stop than one would think, as there is little economic reason to do so. And as Western hyper-consumerism is, among other things, characterized by providing the individual with a multitude of available choices, wasting food as the price of experiencing having these choices might be tempting.

The claim here is that the majority of us do not want to shop at a supermarket where choices are limited, but at one with a wide variety of fresh products – even though this leads to food waste. The same thing happens when we open the refrigerator. In a culture where individuality and freedom of choice is constantly promoted through commercials, there is happiness to be found in being able to ask the question: "what would I like to eat now?" compared to the question: "what do I have to eat?".

This creates a conflict in the individual that is also known in the areas of e.g. climate change and animal welfare. We are caught in a conflict between what we can intellectually understand is the right thing to do according to our values and what we feel like doing, based on our more or

less conscious understanding of what constitutes "a good life"; a conflict between duty and preferences so to speak. And here many of us become "willfully blind", managing to forget what we know or writing down our responsibility to the neglectable to be able to continue living as we do without having to experience cognitive dissonance in our day-to-day lives (Gjerris 2015).

What is wrong with wasting food? – Anthropocentric concerns

In the beginning I described the areas where food waste and loss constitutes a problem in relation to the United Nation's 17 Sustainable Development Goals. It seems clear that it is detrimental to vital human interests and – as long as the waste is of the kinds discussed above – it seems ethically problematic as most ethical theories would find that harming another human being's vital interest to satisfy a non-vital interest is wrong (Gjerris et al. 2013).

One of the interesting aspects of food waste is that it seems to be agreed upon universally as ethically wrong. And often, it seems, not only from an intellectual stance, but also based on a gut feeling that something is inherently wrong. This is probably partly due to the fact of wasting food while around 800 million humans on the planet live in hunger (FAO et al. 2017). And even though it does not make much sense to try to force your children to eat up by reminding them of hungry children elsewhere, as they will never receive the leftovers anyway, it can be seen as an expression of a deep-felt worry that something is wrong, when some of us live in unimaginable wealth whereas others struggle to fulfil their most basic needs.

Two things immediately pop up here. One is that if these concerns really are so deep felt, it seems weird that we do not act more upon them, other than using hungry children elsewhere to try to bring some manners to our own children. This, from my point of view, points back to the "willed blindness" mentioned earlier, which allows us to continue using resources on non-vital needs such as luxury items, holidays etc. while another's vital needs are not met.

The other thing is that reducing food waste in itself is not the whole answer. Going back to the Danish consumers who expressed that the possibility of saving money would be the strongest incentive to reducing food waste, if this money is then spent on practices that are just as damaging to e.g. the climate (flying on holiday instead of taking the train to a local destination) only little is gained. Moving my overconsumption from one area to another will not fill the bellies of hungry children.

What is wrong with wasting food? – Ecocentric concerns

However troubling it is that food waste has the consequences it has for humans around the globe, the question is whether the problem does not go a bit deeper. Perhaps food waste is not only one more example of "man's inhumanity to man" as the Scottish poet Robert Burns famously wrote, but also an expression or a symptom of an understanding with nature that does not give room to nature in its own right, but only to human needs and preferences.

Within environmental ethics there is a distinction between anthropocentric concerns and ecocentric concerns. The first is focused on how an action influences humans. Thus, nature degradation is of ethical concern only if it has a negative influence on humans – nature in itself is only indirectly ethically relevant. Ecocentric concerns, on the contrary, find that nature has an ethical importance itself. It is not only stupid to harm nature as it harms us, but also wrong in itself as nature is part of the ethical community that humans have ethical responsibilities towards.

Ecocentric thinking comes in many colors and flavors (see e.g. Hourdequin 2015). From a virtue-based ecocentric perspective, food waste can be seen as a basic lack of virtues such as humility, awe and respect for and towards nature (see e.g. Hursthouse 2007). Another environmental ethicist, David Abram, talks about the need to understand ourselves as part of a "more-than-human community", if we are to adequately address the crisis that faces us (Abram 1996).

The basic idea is that we belong here. This planet is our home and the biosphere is our extended family. Food waste is wrong not only because it harms humans, but because it harms the larger community we are a part of. And thereby it harms us as well. Following the community analogy, there is no meaningful happiness to be found at the expense of your community. Being part of a community means that your happiness is tied to the happiness of the other members of the community. Happiness is what follows when the community thrives. This might sound as a banality… and it is. But sometimes we cannot see the obvious because we have become too self-obsessed, too willfully blind to accept that we are putting our own preferences above the needs of the communities we live and breathe in.

Oh, what to do?

Caught between what we ought to do and what we want to do when discussing the types of food waste described above (avoidable direct and indirect food waste), the next question becomes: what to do? How do

we act on almost universally agreed-upon values when our hearts cannot follow? Again, the answer might seem like a banality… and again it is. But it is the only one I have: We need to change what we ought to do into something we have a deep-felt desire to do.

Information in itself is not enough. There is nothing wrong with enlightening people about the consequences of food waste in relation to climate change, hunger, loss of biodiversity etc. But it is not enough, because many of us know already and the more we are told, the more we bury our heads in the sand to remain willfully blind and avoid being confronted with our own moral shortcomings.

Indignation in itself is not enough. Some years ago I took my students dumpster-diving and on the inside of the lid of a supermarket container filled with food that was perfectly fine, but just did not fit into the logistics of filling up the shelves and presenting fresh food all the time, someone had written: "if you are not outraged, you are not paying attention". The problem with indignation is, however, that it carries a moral accusation. And most people react to that by pointing at the person bringing on the accusations saying: "Well, how about you?" So it becomes a battle between the morally imperfect and we end up feeling justified by having pointed out that the ones accusing us are just as hypocritical as we are – and (although unrightfully) feeling justified by this.

So what is needed is a change of heart. Virtues. A deep held belief that avoiding food waste is not only the moral thing to do, but a meaningful thing. A thing that makes the community thrive and thereby ourselves. Not in an egoistic manner, but in the sense that we believe that a good life is a life where we carry the responsibility we can and contribute what we can to our community. From this a meaningful existence follows. So we are not acting to secure ourselves or sacrificing ourselves for the sake of others. We are living lives that basically make sense.

This is not easy. Adopting new virtues having been brought up in hyper-consumeristic societies might initially feel like a sacrifice. So duty kicks in and you might have to act against your preferences. Hope lies in that if we try this, we will be given meaningful, good lives – even though they are different from what commercials have brainwashed us to believe in.

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The Contributions of Faith and Spiritual Traditions

Martin Kopp

Introduction

On September 13, 2010, at the age of 23, I left my home country, France, to embark on a several-months-long world travel. It took me to India, Hong Kong, Vietnam, Thailand, Cambodia, Australia, the US, Brazil, and Peru. Of course, part of my round-the-world trip was about fulfilling personal aspirations. For example, I dived with Great White Sharks in South Australia, fulfilling a long-time dream… which I know not every person on this planet shares. But my core goal was to leave the Western cocoon and confront my mind, spirit and body to the reality of the lives of people around the world.

And I did.

I saw a naked old man lying dead in a pile of rubbish on a street in Calcutta. I was solicited by hundreds of beggars, many of whom were children, asking for small amounts of money for food. And often I saw that, right beside sheer misery, a minority would be living a life of indecent wealth and excess, with the food and material they wasted being more than enough to support many others. Each time, my heart ached and cried. So even though I am a young, white, Protestant, French, middle-class male, I am not addressing you out of theory and reading nicely laid-out PDFs. I have witnessed the suffering of those among the 800 million who go hungry or are malnourished. I know the human price of a third of the world's food getting lost or wasted.

Today I work with GreenFaith. As part of this 27-year old global multi-faith organization, I know I contribute to making a difference. With tens of thousands of people of diverse faith and spiritual traditions, we envision a world transformed, in which religious and spiritual communities everywhere generate a moral awakening to the sacredness of Earth and the dignity of all people. We believe that the good life is one of connectedness – with each other and all of nature. It is a world of flourishing life that replaces despair with joy, scarcity with shared abundance, and privilege with justly distributed power. Our mission is to contribute to the building of a global, multi-faith climate and environmental movement.

An ethical issue shared across traditions

Interfaith dialogue is our daily bread. I can bear testimony to the fact that food loss and waste (FLAW) is indeed an ethical issue shared by all faith and spiritual traditions. Each stands on its own theological ground. But all provide a clear moral compass guiding the faithful to be grateful for the nutritious, tasty food that God, the Earth and people's work provide us. All lead us to be mindful of how much we consume, to care about food that might be left over, and to commit to reduce hunger and malnutrition. Other essays in this volume speak to Jewish and Christian teachings on this subject. I would like to broaden the circle and share glimpses of the wealth and depth of other traditions also.

In Islam, a Hadith states that: "Anas (May Allah be pleased with him) reported: Whenever the Messenger of Allah (ﷺ) ate food, he would lick his three fingers and say, 'If anyone of you drops a morsel of food, he should remove any dirt that may have stuck on it and then eat it, and should not leave it for Satan'. He (ﷺ) also commanded us that we should glean the pot, saying, 'You do not know in which part of your food the blessings lies'".[1]

In Buddhism, followers of the Zen tradition and many others practice ōryōki (鉢多羅), an elaborate meal ceremony which literally means taking "just the right amount" of food. The practice of ōryōki synchronizes body and mind through bringing mindfulness to how one eats: one receives food with gratefulness, measures what is enough, and even spares a portion of the meal to make a donation.

In Hinduism, it is taught that "restraint in consumption and simplicity in living represent a path toward *moksha* [मोक्ष] (liberation), which treats the Earth with respect. A well-known Hindu teaching – *tain tyakten bhunjita* – has been translated as 'take what you need for your sustenance without a sense of entitlement or ownership'".[2]

From case studies to key possible joint actions

Theology and spirituality, though, only bloom if they are embodied in people's attitudes and practices. Faith organizations with whom we partner

[1] Hadith provided in its English translation by Hayu Praboho, Chair of the Environmental and Natural Resources Body of the Indonesian Council of Ulamas.

[2] Gandhi, Srinivasan Dr., *Hinduism and Brotherhood*, Chennai, Notion Press, 2018, chapter 13 (Kindle).

are already at work to inspire behavior changes at the personal and institutional levels, and advocate with decision-makers.

For instance, since 2012, the Buddhist Tzu Chi Foundation, which gathers over 10 million members in over 50 countries, has been promoting "The 80/20 Lifestyle". Based on the teachings of its founder Dharma Master Cheng Yen, Tzu Chi invites people to combat food waste by eating only until they are 80% full and use the other 20% to help others. And no one is too young to try: a striking implementation took place at Nibong Tebal kindergarten in Peninsular Malaysia, where teachers encouraged students to save one of the three cookies they were given each day during their daily snack time. Students agreed readily and delivered the collected cookies to low-income families.

This remarkable initiative reminds us that according to UNICEF, about half the world's schools are managed by faith-based organizations (FBOs). Here we have a first lead for enhanced collaboration: FBOs that manage schools represent powerful allies to promote a healthy, just and sustainable use of food, at ages ranging from childhood to adolescence, when behaviors are often shaped for a lifetime.

Let's stay in Asia for my second example. The Environment and Natural Resources Body of the Indonesian Council of Ulamas – which is the theological authority of the most populous Muslim country in the world – has developed an Excess Food sharing program. Instead of being wasted, unsold or unused food (which is different from leftovers) is gathered from restaurants, hotels, cafes, and canteens, and is distributed to people in need. In Jakarta, in the last two and a half months, 10 volunteers collected excess food from 11 donors, gathering enough to prepare 1,650 food packs, which were distributed to about 80 people in need. This local story proves that reducing food waste and loss, tackling the climate emergency, and addressing the impacts of poverty can all go together. Such a win-win approach – which Pope Francis calls "integral ecology"[3] – is of particular importance to many faith actors, who put caring for the most vulnerable at the heart of their work.

Here we find a second lead for increased joint action: innovative cross-issue partnerships can be imagined between FBOs, food producing companies and social organizations. Projects like this would also help to disprove the idea that taking care of the Earth means giving priority to the planet

[3] See: Pope Francis, *Laudato Si'. On Care for Our Common Home*, 2015.

over the poor, as if there were a competition between the two urgent matters. This misconception is often still encountered in the religious world.

Allow me to share a final example. In 2018 the Global Catholic Climate Movement held a "St. Francis Sunday" in Kraków, Gdańsk, Poznań, and Toruń, Poland. At these events, country-specific information about food waste was shared in churches, and a "St. Francis Pledge" was signed by high-level religious leaders, including Catholic Bishops, the Polish Minister of Agriculture, the President of UNFCCC COP24, and parishioners around the country. The pledge called for the reduction of food waste and the associated greenhouse gas emissions and committed signatories to make changes themselves. Twenty-one media outlets covered the events, reaching an audience of over 2 million Poles.

This final case study shows how wide an audience faith leaders and religious institutions can reach, when they commit publicly, communicate through official channels, and talk to the media. It also illustrates well that in many places religious leaders have access to high-level decision-makers nationally and internationally. That is my third and last key lead for ramped-up impact by religions: through high-level leaders, there is great potential for advocacy with people in power and influence over a very wide audience.

Bringing religious action up to scale

At the beginning of my contribution, I took the time to quote sacred scriptures. Being rooted is vital, for it reminds us of the specific strength of religions and spiritualities among agents of change: we are vehicles of worldviews, beliefs and values which, when shared effectively and held deeply, determine attitudes and behaviors. We are not speaking of millions of people here, but of billions – actually over 8 out of 10 persons on this planet, according to the Pew Research Centre.[4] But let's be honest, while religions represent a formidable potential for change, their action has not been brought up to scale.

At GreenFaith, we want this to change. And we come to the table with a concrete idea. Around the world, locally, people of different faiths and spiritualities are beginning to come together to form GreenFaith Circles – Communities of Care and Resilience. The members of these Circles meet regularly – at a church or temple, around the kitchen table of one of

[4] Pew Research Centre, *The Global Religious Landscape. A Report on the Size and Distribution of the World's Major Religious Groups as of 2010*, Washington, D.C., Pew Research Centre's Forum on Religious and Public Life, 2012, p. 9.

their members, or in another comfortable location. They work together on three "pathways to power", areas of activity in which religious people must take action to help heal our precious planet. Action at the system level – political and economic – is vital, as is action at the institutional level, the level of our parishes, mosques, temples and religious schools. The third pathway to power is that of individual transformation, which includes shifting behavior. These small groups represent the living cells of a global community, and they are vital because we change most readily and most often when we are in relationship with others. When Circles meet, we encourage them to share a plant-based meal, inviting them to live the change that they want to see in the world.

When we offer guidance on individual behavior change to our Circles, we focus on the three areas which have the biggest impacts: transport, diet, and home energy use. Among possible changes in the diet area, we are promoting the reduction of food waste at home by 50%, and we encourage people to report to each other in their Circles about how they are progressing in this and other areas. It might not seem much, but we have learned that what matters is to lead people on a path of change which begins with a manageable first step. Presenting people with the end result at the outset often makes the climb seem impossible. It's far more effective, and therefore important, to enable people to begin the journey, and to provide accompaniment that enables them to travel much farther together than they ever could go alone.

We believe it is smart to take the fight against climate change as an entry door to sensitize and motivate people of faith about food waste. For the climate emergency has become a top issue of concern worldwide, especially among young people – no less than 7 million people filled the streets in September 2019. And the impact of food waste is staggering: according to the FAO, internationally food waste produces more greenhouse gas emissions than any single country except China and the US.[5] In fact, it produces more greenhouse gas emissions than Brazil, Indonesia, Mexico, and Canada combined! By lowering their food waste, participants are in a win-win situation: they help the planet, fight hunger, take care of the future, and embody their values of simplicity and justice.

[5] FAO, *Food wastage footprint. Impacts on natural resources. Summary Report*, Rome, FAO, 2013, p. 17.

Final offering

As we move forward into a challenging future, we are exploring the development of resources in multiple languages to support people of different faiths, and the faith-based communities to which they belong, to organize a *Food Waste Weekend*. On this weekend, they would offer a sermon, homily, *qhutbah*, *dvar torah*, *dharma* talk or other spoken teaching to educate their members or followers about the moral imperative of ending food waste. We would provide practical tips about how to do this, supported by teachings from their religion. We would invite these institutions and their members to make a pledge to reduce or eliminate food waste, and we would provide ongoing tips and reminders during the year about why and how to do this. This would be the first time a global, multi-faith community came together to focus on this vital issue. We have the relationships and the ability to make this happen and would welcome the chance to explore this with any of you who find it interesting.

We can solve the problems of climate change and food waste only if we come together as a community, only if we celebrate our diversity and our similarities, only if we learn together what it feels like and what it means to create a world truly governed by love, justice and compassion. With partners around the world and from a joyous variety of religions and spiritualities, GreenFaith has begun that journey. Will you join us?