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Minimising food waste: a call for multidisciplinary research

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Abstract

Food losses and waste have always been a significant global problem for mankind, and one which has become increasingly recognised as such by policy makers, food producers, processors, retailers, and consumers. It is, however, an emotive subject whereby the extent, accuracy and resolution of available data on postharvest loss and waste are questionable, such that key performance indicators on waste can be misinformed. The nature and extent of food waste differ among developed economies, economies in transition and developing countries. While most emphasis has been put on increasing future crop production, far less resource has been and is still channelled towards enabling both established and innovative food preservation technologies to reduce food waste while maintaining safety and quality. Reducing food loss and waste is a more tractable problem than increasing production in the short to medium term, as its solution is not directly limited, for instance, by available land and water resources. Here we argue the need for a paradigm shift of current funding strategies and research programmes that will encourage the development, implementation and translation of collective biological, engineering and management solutions to better preserve and utilise food. Such multidisciplinary thinking across global supply chains is an essential element in the pursuit of achieving sustainable food and nutritional security. The implementation of allied technological and management solutions is reliant on there being sufficient skilled human capital and resources. There is currently a lack of robust postharvest research networks outside of the developed world, and insufficient global funding mechanisms that can support such interdisciplinary collaborations. There is, thus, a collective need for schemes that encourage inter-supply chain research, knowledge exchange and capacity building to reduce food losses and waste.

Keywords: postharvest loss; sustainability; food security; fresh produce

THE BALANCE BETWEEN INCREASING FOOD PRODUCTION AND MINIMISING WASTE

The world's population is predicted to reach 9.6 billion people by 2050.[1] To support this burgeoning population, projections are centred on increasing food production by at least 70%, rather than also reducing food loss and waste.[2] The challenge of guaranteeing food security has never been greater. Food security is a dynamic concept that has changed over recent decades. It was originally defined at the 1974 World Food Summit, with the focus on the volume and the stability of food supplies. However, over time the definition has evolved to capture a more complex and multidimensional concept comprising nutrition, safety and sociocultural aspects.[3] In this context, the current four dimensions of food security are availability, accessibility, utilisation and stability of food provision.[4,5]

According to recent forecasts, increases in productivity will also need to be based on higher cropping intensities,[6] but there will be major challenges in reconciling increased irrigated crop production with water resources availability. The World Economic Forum 2015 identified the 'water crises' as one of the top five global risks to society due to the multifunctional impact of water on socioeconomic development, health and sanitation, aquatic ecosystems and agricultural production.[7] The global demand for water continues to rise steadily due to increases in world population and consequent changes in dietary habits and living standards, and support for socioeconomic development.[8] Climate change, with greater climate uncertainty and extremes, will exacerbate the impacts on water resource availability and crop productivity particularly in food-insecure regions including South Asia and sub-Saharan Africa.[9] Considering the limited and often exhausted resources we have access to, food loss and waste should be avoided as far as possible, as it implies additional environmental impacts such as methane and carbon dioxide emissions that may aggravate climate change[10,11] and ecosystem deterioration. As such, food waste has become increasingly recognised as a global problem by policy makers, food producers, processors, retailers and consumers.[12] More sustainable food systems with both improved agricultural efficiency and better supply chain management are required.[13]

A supply chain can be defined as a network that integrates growers, processors, manufacturers, wholesalers, retailers (and consumers) coordinating the flow of products, information and money between actors in production and consumption.[13,14] According to Irani and Sharif,[15] the main players or areas involved in the food supply chain are the economic sector (market pricing,

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demand management, financial metrics and consumption trends), agriculture (improving cultural practices and management to increase sustainable production), postharvest technology (processing, storage, transportation and quality control), and environment. Closer communication and collaboration among those multidisciplinary stakeholders would promote more sustainable supply chains, which will lead to a reduction in the current food loss and waste.

IMPACT OF FOOD LOSS AND WASTE ON FOOD AVAILABILITY/SUSTAINABILITY

Currently, it is thought that one-third of the world's overall food produced by weight is lost or wasted[16,17]; however, the accuracy and usefulness of these broad statements are questionable. This is not to say that food waste is not a significant problem and that raising the issue is not important – quite the contrary. The extent, accuracy and resolution of available data on postharvest loss and waste are generally problematic since often methodologies are not forthcoming, not sufficiently robust or not clearly set out. As a result, the overall message is focused too much on the extent of overall food waste rather than what should be done about it according to geographic and temporal resolution and need.

Definitions of food loss and waste are not universal. In general, food loss encompasses the reduction in the edible food dry mass or nutritional value across the supply chain (growing, harvest, processing, production, storage, transport and distribution). Food waste is part of food loss; it commonly occurs in developed economies at both the retailer and consumer end, as a result of either poor planning or business decisions, as well as lack of technological infrastructure, capabilities or consumer awareness.[18] Postharvest losses partly depend on the available technology in any one country and, henceforth, on its agricultural and industrial development. Parfitt *et al.*[19] consider these losses along a technological/economic gradient: 'developing', 'intermediate' and 'industrialised' food supply chains. The main causes of food loss and waste in developing countries originate from either cultural influences and/or financial, managerial and technical resource constraints on harvesting techniques, cooling technologies and storage facilities.[18] Fruit and vegetables are the category with the highest amount of losses and waste, followed by meat, fish and seafood, and milk; and within the fruit and vegetables the highest losses occur at the processing and packaging stage.[20,21] Where a nation's development moves into a transitional phase, food loss is seen further along the food supply chain (storage and retailer rather than just production and transportation). In developed countries, the highest contribution to food waste often occurs at household level (e.g. 71% in the UK).[12] At every step of the supply chain, food waste has an impact on economic (direct loss for farmers, retailers and consumers), social (failure to secure food for a wider population) and environmental aspects (soil, water, energy implications and GHGe: greenhouse gas emissions). Terry *et al.*[21] reported that the fruit and vegetable sector accounts for about 2.5% of the UK's overall GHGe. Potato has one of the highest levels of GHGe, mostly because of the energy needed for cooking in the home. Garnett[22] highlighted waste as the major area contributing to GHGe within the UK fruit and vegetable sector, with most of the waste occurring at household and food service levels. It was reported that air freight and refrigeration are hotspots in the life-cycle analysis of fresh produce, whereby the former accounts for approximately half of all GHGe associated with transport. Other factors that contribute to waste, mostly in developed countries, are: (i) how 'quality standard specifications' are set (aesthetic *vs.* nutritional or safe)[11,22]; for example, UK customers (retailers) tend to set their own quality standards for suppliers, which can be over and above the regulatory standards[23]; (ii) consumers' lack of understanding/misconception of food labelling – e.g. sell by, best before, consume by and expiry date[24]; moreover, results from structured interviews with UK retailers, wholesalers, suppliers and others showed that consumers were also confused by the ubiquitous use of promotions ('promotion fatigue'),[23] which could eventually lead to food waste at household level when buying more than what was needed. These examples illustrate that food waste can be tackled from different angles both by implementation of technological and innovative supply chain management interventions, and by changing attitudes and behaviour. As food waste not only impacts on a single sector but also on multiple segments of society and the environment, several different indicators for the level of food waste should be considered. From an economic point of view, one can monitor the waste at every step in the supply chain: rate of soil loss *versus* regeneration; percentage of production resource wasted; energy input per unit of production; nutritional losses; quantity of harvest lost due to pests or diseases. Wasting food is primarily a social concern, given that 800 million live under extreme poverty[25] and hunger.

THE WAY FORWARD TO REDUCING FOOD LOSS AND WASTE

Despite the recognised negative impact of food waste on the environment, economy and wider society, the worldwide evolution of food waste has steadily increased from 2004 to 2013 (Fig. 1). That said, the difficulty and complexity of collating exhaustive food loss and waste data must be noted; greater data transparency is required both throughout the supply chain and among countries. In this context, clear accountability would be a prerequisite for benchmarking, and managing and reducing waste.[23] Data presented herein (Fig. 1) was taken from the FAOSTAT database and is focused on grain, fruit and vegetable losses, which are most affected by postharvest processes and storage conditions. The total amount of food loss in 2013 was ~430 Mt.[16] It is not only that the absolute total amount of food loss has increased as a result of a growing world population over the last decade but, what is more remarkable is that the contribution per capita to food waste has increased (e.g. 47.2 and 62.4 kg per capita in 2004 and 2013, respectively).[16]

Research and technological innovation should be the drivers for reducing food loss and waste by establishing true translation between industrialised and developing countries. Yet, substantially more targeted and appropriate research should be carried out and implemented directly in low- and middle-income countries; taking into account their particular circumstances and potential limitations (e.g. economic frameworks, infrastructures, energy supply and resilience, cultural and societal practices and behaviours). Appropriate postharvest innovation is not just reliant on available postharvest human capital (Fig. 2) but also on available funding mechanisms. Europe is one of the dominant areas for postharvest research, and has a relatively low input to global food loss.[16] In Africa, on the other hand, which contributes approximately 18% of global postharvest food losses, the research base is too low across the continent, with the majority of research stemming from South Africa. In general, there is a paucity of active research being conducted in areas where postharvest fresh produce loss is greatest. There is a lack of mechanisms such as

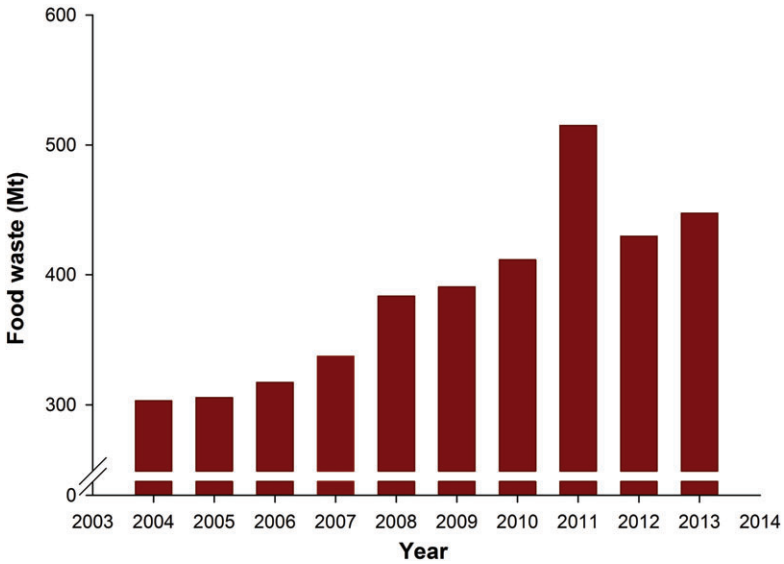

Figure 1. Food loss (grains, fruit, vegetables and derivatives) evolution in weight (megatonnes, Mt) per year from 2004 to 2013 according to FAOSTAT Statistics Database.[16]

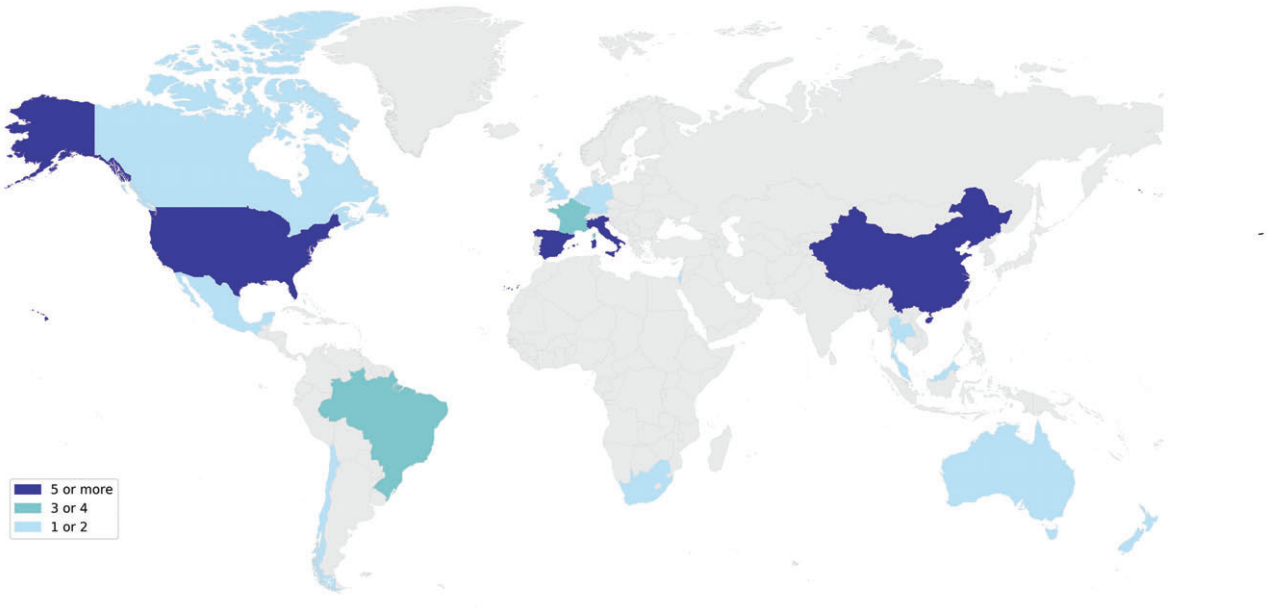

Figure 2. World map showing where the 50 most active postharvest research institutions are located. Darker colours indicate higher number of research institutions for a specific country, whereas a lighter colour indicates a lesser number of institutions within a country. The institutions have been ranked by cross checking: i) Scopus statistics regarding first author's affiliation from peer reviewed publications - after filtering by keyword ('postharvest') AND postharvest related journals (viz. Journal of the Science of Food and Agriculture, Postharvest Biology and Technology, International Journal of Food Science, amongst others, were included) AND year (2006–2015); and ii) ISHS International Postharvest Symposium presenters. Data herein cover a ten year period, from 2006 to 2015.

knowledge transfer programmes, and internationally funded joint research and mobility schemes across supply chains, by which both conventional and innovative technologies can be developed and further implemented across the globe to reduce waste. Where collaboration does exist, it is usually carried out on a bilateral basis, which tends to ignore the geographic and temporal complexity and interconnectivity of modern global supply chains.

CONCLUSIONS

Food loss and waste is a complex problem that occurs at all stages of the supply chain, with many stakeholders involved. Causes range from inadequancies in storage technologies and facilities, as well as demand forecasting and inventory planning issues. Behavioural attitudes of consumers have the greatest impact on the highest value-added food waste. There is a lack of skilled human capital, and the existing networks of researchers focusing on food loss and waste are not fully connected. To tackle this global problem a multidisciplinary and collaborative research paradigm shift is required bringing together biological, engineering and behavioural economics research that provides robust data and solutions to reduce horticultural produce losses. Future efforts could be encouraged through providing funding schemes for recruiting highly qualified scientists and

network building incentivising new frameworks to facilitate interdisciplinary collaborations.

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