RESEARCH ARTICLE

Framing food security and food loss statistics for incisive supply chain improvement and knowledge transfer between Kenyan, Indian and United Kingdom food manufacturers [version 1; peer review: awaiting peer review]

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Abstract
The application of global indices of nutrition and food sustainability in public health and the improvement of product profiles has facilitated effective actions that increase food security. In the research reported here we develop index measurements further so that they can be applied to food categories and be used by food processors and manufacturers for specific food supply chains. This research considers how they can be used to assess the sustainability of supply chain operations by stimulating more incisive food loss and waste reduction planning. The research demonstrates how an index driven approach focussed on improving both nutritional delivery and reducing food waste will result in improved food security and sustainability. Nutritional improvements are focussed on protein supply and reduction of food waste on supply chain losses and the methods are tested using the food systems of Kenya and India where the current research is being deployed. Innovative practices will emerge when nutritional improvement and waste reduction actions demonstrate market success, and this will result in the co-development of food manufacturing infrastructure and innovation programmes. The use of established indices of sustainability and security enable comparisons that encourage knowledge transfer and the establishment of cross-functional indices that quantify national food nutrition, security and sustainability. The research presented in this initial study is focussed on applying these indices to specific food supply chains for food processors and manufacturers.

Keywords
Kenya, India, food security, sustainable development, food sustainability

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Introduction

Current models and indices of food security and sustainability identify high level policy risks and as such they focus on the production of agricultural commodities and provide little understanding of resilience in the manufacturing, distribution and retailing functions of supply chains (Notarnicola *et al.,* 2017). This is important because it is the development of industrial infrastructure that has consistently delivered resilience in food supply chains when projections of 'peak resource' models have not provided accurate projections. This is because models based solely on limiting carrying capacity overlook values associated with sustainable supply chains such as those of contractual trust and organisational cultures (White & Gardea-Torresdey, 2018). It is increasingly important to understand resource limits of food production systems with respect to these commercial attributes and improving the tools to do this remains crucial (Izraelov & Silber, 2019). The measurement of the success of product innovation in small and large manufacturing companies alike is realised in the provision of consumer fulfilment of manufactured foods. Their value is rarely mentioned as a contribution to sustainable food supply and the need for manufacturer relevant assessments could be established for greater food security (Ingram & Porter, 2015). That is, if products deliver what consumers require and sustainable attributes are built into their product development such as optimal nutrition and resource use then more secure and sustainable outcomes are observed.

Food security is defined as the state in which people at all times have physical, social and economic access to sufficient and nutritious food that meets their dietary needs for a healthy and active life. This framework is based on the internationally accepted definition established at the 1996 World Food Summit (Pinstrup-Andersen, 2009). The interaction of food security with nutritional goals and food supply chain sustainability do complement and this complementarity focusses the need for food industry guidance at product development level (Gustafson *et al.,* 2016). The global food system in 2050 will have to supply nine billion people with meals three times a day in a safe and sustainable way that is delivered by a secure food industry. This means food products must be affordable, available and assured so that they can be prepared for meals, which raises the importance of understanding the role of new product development (NPD) in this future world system (Martindale, 2017a). NPD processes must take a concept to consumer approach so that sustainability is built into the NPD process and food waste is removed from the food system. The concept to consumer design approach will mean food products will be developed for utilisation in meals and therefore result in improved nutritional, food waste and sustainability outcomes.

Product developers are keystone operators for enabling food sustainability and they must begin to take a long-term view for continuous improvement in these processes. This will require a step back from typical NPD operations to take stock of what successful product development means for consumer diets at a population or meta-NPD level (Martindale *et al.,* 2019). Product developers will increasingly be asked to link the constraints of food product design with high level targets, such as the UN's 17 Sustainable Development Goals that cross the health, social wealth and environmental lenses of sustainable food supply (Casini *et al.,* 2019). Consumer choice will need to be at the core of getting food product development right and a starting point for developing NPD strategies guided by these principles is to use national level consumption statistics for the most popular food choices. Switching or nudging consumer choices of foods to more sustainable dietary options is not only possible, it has already happened for protein choices where it was considered unthinkable not that long ago that meat free products would dominate retail and service offers driven by consumer demand (Sachs, 2012). Many NPD functions find themselves trying to catch up with this shift in consumer attitudes and the diversification of protein choices is an important focus for future dietary sustainability in the global production and export arenas (Apostolidis & McLeay, 2016).

An analysis of the demand for different protein categories is important globally and it requires associative data analysis techniques which are tested in this reported research which identifies pressure points associated with the movement of resources within and across supply chains. It is also the nutritional quality of food materials that determines demand and it is rarely considered because food volume and price dominate even though research has tested sustainability reporting on a calorific basis (Drewnowski *et al.,* 2015). Protein content is used in this research as a nutritional indicator in the Centreplate Model developed to rank and associate food materials based on their protein supply in diets. It is the measurement of nutritional value and the risk of food being wasted that provide resonant consumer communications because food that is not fully utilised will result in any resources used to manufacture it being lost. It is this insight on the utilisation of foods by consumers that is the core principle here and it conveniently connects the sustainability attributes of nutritional improvement and waste reduction, which are universally desirable impacts across supply chains (Martindale, 2017b).

There is recognition that improvements in obtaining supply chain data will create a step change and digital technologies offer much promise in improving data capture by operators across supply chains. That is, local data and bespoke data captured by food companies could be of great value in future and the use of indices of security and sustainability would result in reportable good practice (Martindale *et al.,* 2018). Real-time supply chain data is a future capability that can be provided by recently tested applications of cloud-based data transfer that is secured by distributed ledger technologies (DLTs) in the food industry (Pearson *et al.,* 2019). When the algorithms for assessing sustainability become transferable to all supply chain partners, it is the communication of them that becomes guiding (Sautron *et al.,* 2015). This is dependent on scaling data to the national and global food marketplaces where the ability to obtain verified and transparent data for products in these supply chains has previously limited sustainability assessments of consumer goods. This is now being overcome by integrating machine learning technologies with data carriers such as low cost radio frequency identification tags which are used as on-pack labels that ensure secure supply chain records are available (Liakos *et al.,* 2018). Their application in sustainability assessment is only beginning to be tested, as in the case of waste reduction where more efficient inventory planning will mean quality is maximised and dramatic reductions in household food waste will be observed. The metrics and algorithms used to associate different food categories are tested in this research so that they can provide communications that resonate with consumers (Berry *et al.,* 2015).

Methods

The association with protein supply as a nutritional benchmark is tested and the amount of food waste associated with different food categories is obtained from FAOSTAT data. The opportunity to test the Centreplate Model with the food and beverage systems of India, Kenya and United Kingdom is utilised in this research and it explores the potential of knowledge transfer of incisive food waste reduction actions within supply chains. This research test a method that was developed to enable national protein supply for different food categories to be related to domestic supply quantity (DSQ, tonnes per year, the product of [production + imports] - exports+ changes in stocks (decrease or increase)) and food loss data. The method has been used to identify critical control points for increasing food security and reducing food losses across supply chains. The method has been called the Centreplate Model because it identifies protein diversity across national diets and it is used to guide policy makers who wish to identify improvements in protein supply (Martindale, 2017a). This is achieved by association and ranking techniques that benchmark data to protein supply statistics. The food categories used in the analysis are those used by the FAOSTAT database available at the time of writing (FAOSTAT, 2019).

The protein content of food supply is used as a benchmark for dietary requirements in this study because of the protein content of foods is a major driver of dietary change. The FAOSTAT open access databases for Food Supply – Crops, Livestock and Fish Primary Equivalent for the most recent year, which was 2013, were used to obtain the data for dietary protein supply benchmarking in this research. This data was used to test the Centreplate Model and the value of using relative rank and association methods. The benchmarking of protein supply was carried out by selecting crop and livestock primary equivalent product categories and their protein supplied on grams protein per Capita per Day basis for Kenya, India and United Kingdom. The quantities for livestock and crop food categories were then ranked from greatest to least protein quantity supplied. Further ranking analysis was carried out from greatest to least across the livestock and crop categories for domestic supply quantity and food losses (tonnes of supply chain losses per year). This provides an indicator of protein diversity because the data sets are ranked with respect to DSQ and food loss and associated to the ranked protein supply data by the DSQ order number. The rank and associative order enables the identification of protein supply chains and protein diversity for national food systems.

The Centreplate Model outcomes are guided with reference to the Global Food Security Index (GFSI) (Chen *et al.,* 2019). The use of the GSFI is also discussed with respect to other indices including the Global Access to Nutrition Index (ATNI) and Food Sustainability index in this reported research (Gustafson *et al.,* 2016; Haddad, 2018). The GFSI will provide an important means to test knowledge transfer actions and insight at national levels for the food category level assessed in the Centreplate Model. It is important to identify where existing indices such as the GFSI identify strategic data as strengths or challenges at national levels and where the Centreplate Model identifies food category strengths or challenges at a more granular level. This is because the Centreplate Model data and metrics will be of use to food manufacturers at local levels who wish to improve their product development strategies.

The data analysis shown in Table 1 to Table 5 uses protein supply data from FAOSTAT commodity balance datasets agri-commodity food groups. The protein supply data was ranked from highest to lowest and benchmarked against DSQ and food loss ranked data. The MATCH function in MS Excel was used to measure the ranking order difference between the food group protein supply rank and DSQ or food loss rank. This provides a measure of where protein supply was greater than or less than the DSQ or food loss rank order for the protein supply rank of that food group. The FAOSTAT open access databases for Food Supply—Crops, Livestock and Fish Primary Equivalent, were used for dietary protein supply benchmarking for the last public domain reported year, 2013. The protein supply for each food category is used to benchmark the ranking of production, Domestic Supply Quantity (DSQ) and food loss. DSQ is (production + imports) - exports + changes in stocks (decrease or increase) = supply for domestic utilization. The food losses reported by FAOSTAT are the amount of the commodity in question lost through wastage (waste) during the year at all stages between the level at which production is recorded and the household, i.e., storage and transportation. Losses occurring before and during harvest are excluded. Waste from both edible and inedible parts of the commodity occurring in the household is also excluded. Quantities lost during the transformation of primary commodities into processed products are considered in the assessment of respective extraction/conversion rates.

Results

Table 1 and Table 2 show the rank of protein supply for the Indian and Kenyan food system across different food material categories using grams of protein per capita per day benchmarked against DSQ rank scores. Where DSQ of a specific crop or livestock product category is ranked lower than the protein supply it is a pressure point on supply. Where DSQ is ranked higher than protein supplied it represents an opportunity to develop a specific crop or livestock product category as a protein supply. Table 1 and Table 2 show where there are ingredient opportunities and whether they are reliant on increasing production or imports. The approach of ranking and benchmarking to protein supply also identifies where there are potential surpluses of ingredients for the supply of protein.

Table 1. The rank of protein supply for the Indian food system across different food material categories, the rank score of protein supply benchmarked against domestic supply quantity (DSQ) rank scores. The ▼ symbol for DSQ shows points where DSQ rank is lower than protein rank; the ▲ symbol shows points where DSQ rank is greater than protein rank.

Food item category	Protein supplied in grams per capita per	The protein supply to DSQ ranking comparison
1.Wheat and products	15.09	6▼
2. Rice (Milled Equivalent)	12.96	5▼
3. Milk - Excluding Butter	8.17	4▼
4 Pulses, Other and products	5.5	19▼
5. Vegetables, Other	2.43	7▼
6. Millet and products	1.94	25▼
7. Beans	1.78	34▼
8. Maize and products	1.29	16▼
9. Roots & Tuber Dry Equiv	1.14	22▼
10. Potatoes and products	1.07	9▲

Table 2. The rank of protein supply for the Kenyan food system across different food material categories, the rank score of protein supply benchmarked against domestic supply quantity (DSQ) rank scores. The ▼ symbol for DSQ shows points where DSQ rank is lower than protein rank; the ▲ symbol shows points where DSQ rank is greater than protein rank.

Food item category	Protein supplied in grams per capita per day	The protein supply to DSQ ranking comparison
1. Maize and products	17.47	4▼
2. Wheat and products	7.73	7▼
3. Milk - Excluding Butter	7.65	2▲
4. Beans	6.34	19▼
5. Bovine Meat	3.85	24▼
6. Roots & Tuber Dry Equiv	3.29	11▼
7. Pulses, Other and products	2.79	27▼
8. Rice (Milled Equivalent)	2.35	18▼
9. Potatoes and products	1.72	5▲
10. Vegetables	1.22	6▲

Table 3. The rank of food losses for the Indian food system across different food item categories, the ranked amount of food losses from producer to retailers (tonnes) are benchmarked against domestic supply quantity (DSQ) rank scores. The ▼ symbol for DSQ shows points where DSQ rank is lower than food loss rank; the ▲ symbol shows points where DSQ rank is greater than food loss rank.

Food item category	Supply chain loss as defined by FAO in tonnes per year	The supply chain loss to DSQ ranking comparison
1. Potatoes and products	11335900	9▼
2. Wheat and products	5611298	6▼
3. Bananas	5515000	12▼
4. Sugar cane	5118000	1▲
5. Milk - Excluding Butter	4878251	4▲
6. Rice (Paddy Equivalent)	4776000	5▲
7. Vegetables, Other	4668008	7
8. Fruits, Other	4446674	10▼
9. Roots & Tuber Dry Equiv	2390450	22▼
10. Maize and products	2330163	16▼

FAO, Food and Agriculture Organization of the United Nations.

Table 4. The rank of food losses for the Kenyan food system across different food item categories, the ranked amount of food losses from producer to retailers (tonnes) are benchmarked against domestic supply quantity (DSQ) rank scores. The ▼ symbol for DSQ shows points where DSQ rank is lower than food loss rank; the ▲ symbol shows points where DSQ rank is greater than food loss rank.

Food item category	Supply chain loss as define by FAO in tonnes per year	The supply chain loss to DSQ ranking comparison
1. Milk - Excluding Butter	341267	2▼
2. Potatoes and products	219365	5▼
3. Bananas	209747	8▼
4. Sweet potatoes	115036	9▼
5. Beans	91804	19▼
6. Roots & Tuber Dry Equiv	84264	11▼
7. Maize and products	73688	4▲
8. Fruits, Other	73171	12▼
9. Vegetables, Other	72577	6▲
10. Tomatoes and products	50447	21▼
11. Molasses	36918	29▼
12. Cassava and products	33373	10▲
13. Wheat and products	31378	7▲

FAO, Food and Agriculture Organization of the United Nations.

Table 5. The rank of DSQ and food losses (from producer to retailers) for the United Kingdom across different food item categories, these are benchmarked against domestic supply quantity (DSQ) rank scores. The ▼ symbol for DSQ shows points where DSQ rank is lower than protein rank; the ▲ symbol shows points where DSQ rank is greater than protein rank. For food loss the ▼ symbol shows points where food loss rank is lower than protein supply rank; the ▲ symbol shows points where food loss rank is greater than protein supply rank.

		Rank value	
	Protein supplied in grams per capita per day	DSQ	Food loss*
1. Wheat and products	24.25	2▼	2▼
2. Milk	19.05	1▲	0
3. Poultry Meat	12.78	10▼	0
4. Pigmeat	7.12	14▼	0
5. Bovine Meat	6.45	18▼	0
6. Potatoes and products	4.17	4▲	3▲
7. Eggs	3.43	22▼	15▼
8. Vegetables, Other	2.34	6▲	1▲
9. Demersal Fish	2.2	28▼	0
10. Oats	1.59	23▼	16▼

*Note, zero values are reported to FAOStat, these are standardised data.

Table 3 and Table 4 show the rank of food losses for the Indian and Kenyan food system across different food item categories; the ranked amount of food losses from producer to retailers (tonnes) are benchmarked against DSQ rank scores. The pressure points are indicated here where DSQ is ranked lower than the food losses for that category, and opportunities or good practice are identified where DSQ is ranked higher than food losses. Table 5 shows the analysis for protein benchmarked to DSQ and food loss for the United Kingdom. Food loss is not benchmarked to DSQ for the UK where import considerations are well described and where food loss is ranked greater than protein supply there are opportunities to improve losses.

Table 6 shows a summary of the results derived from Table 1 to Table 5 presented as a matrix of supply chain interventions for developing protein categories. These are focussed on preservation techniques and fit-for-purpose packaging where innovations are proven to diversify protein choices and reduce food waste.

Table 6. An analysis of the Kenyan and Indian food supply chains using a supply chain matrix approach which identifies universal supply chain functions for reducing food waste and improving product quality.

Supply chain location	Example	Impact	Interventions and solutions
On farm.	Losses in field due to sub-optimal farming practice. Losses due to produce perishing post-harvest on site at farm.	Higher than standard in-field crop losses. Increased losses of produce – increased wastage.	Training and awareness of ideal growing and harvesting techniques to reduce in field losses. Low cost cool storage solutions. Improved packaging / handling practices.
Post harvest processing and packaging on farm or in co-operative / shared / commercial facilities.	Losses due to product perishing as insufficient shelf life.	High wastage.	Awareness and availability of Post-harvest processing equipment. E.g. Dryers to extend shelf life. Incorporation in processed foods. Improved packaging systems to reduce physical damage in handling / transit / storage and also to reduce moisture build / spoilage.
Cool stores.	Large scale cool storage (and Controlled Atmosphere for some crops) facilities.	Improved shelf life and handling systems.	Advance the design and practices in Cool Storage facilities. Influence policy to encourage best practice in waste reduction, shared value with small holder farmers and in design for energy efficiency.
Production for export markets	Green beans, baby corn, broccoli, sugar snap peas and high value vegetables.	Rejected quality on delivery of consignment. Lack of visibility of options for export. Lack of supply chain options for export.	Retail standards enforced at all supply chain function (producer through to exporter). Data management of current inventory and transaction (when product is moved from stakeholder A to stakeholder B). Category management for retailer.
Distribution and storage.	Lack of cold chain / refrigerated transport infrastructure. Food staples and key protein and carbohydrate supplies.	Climates of high RH and temperature impact fresh produce with high spoilage rates. Unfavourable selection of food categories and low diversification of diet and protein choices.	Increased awareness of the benefits of cool and/or dry chain – will lead to investment and availability of cool chain options – reduced wastage – shared value across the supply chain vital to make such interventions viable. Potential for Meta NPD solutions.
Manufacturing.	Diversification of packaging e.g. for whole milk.	Increased shelf life.	Meta NPD, improved health and reduced waste.
Retailers and consumer selection of quality produce.	Damaged fruit and vegetables.	Unselected produce that is damaged is wasted after being transported. Creation of pressure points, the demand for foods that have low DSQ increases.	Retail standards enforced at all supply chain function (producer through to retailer). Supply chain training on storage and transportation. Identification of alternative product development-diversion of lower visual quality produce is used in Makueni County for juicing, supported by government.

RH, relative humidity; NPD, new product development; DSQ, domestic supply quantity.

Discussion

The GFSI identifies complementarity and association in food security data where the Indian and Kenyan GFSI shows food loss reduction is 1.5% to 2.5% above the global mean and it is therefore qualified as a strength. This means food losses are close to the global mean; it does not mean there is no need to reduce food loss because we expect a food loss score of >95 in nations where food supply infrastructure supports refrigerated preservation and advanced forms of inventory management. This relationship identifies a weakness in the use of national indicators and benchmarking for supply chains and meals is required to call for improvement. The GFSI identify public expenditure on research and development and gross domestic production (GDP) limitation are challenges with protein diversity. These are important indicators for developing interventions for policy because research investment can be focussed on creating efficient supply chains that design out food losses and waste. The issue of protein diversity limitation also establishes a target for policy improvement because product development in the food manufacturing and processing industries can stabilise, preserve and provide new sources of protein products that will appeal to consumers.

Table 1 and Table 2 show that protein supply is limited by DSQ across most preferred protein categories, identifying a requirement to improve production and decrease reliance on imported protein categories. In India, potatoes are the only food category where there is potential to increase protein supply within current DSQ (Table 1). In Kenya; Milk, Kenyan potatoes (European table potatoes) and vegetables are the food categories where there is potential to increase protein supply with current DSQ (Table 2). The specific pressure points in India where protein supply rank order is greater than the DSQ rank order is observed for wheat, rice, pulses, millet, beans, maize, roots and freshwater fish which is 13th protein rank, 35th DSQ rank (not all categories rank order are shown on Table 1). Bananas (21st protein rank, 12th DSQ rank) and fruits (22nd protein ranked, 10th DSQ rank) do also present protein fortification opportunities because the DSQ rank order is greater than the protein supply rank order. Wheat presents an important challenge in Table 1 and Table 2 because of reliance on imports and increased supply chain losses identified in Table 3 for Indian wheat supply. The specific pressure points where protein supply rank order in Kenya is greater than DSQ rank order is apparent for most food categories, emphasising the restriction of food supply by production and fiscal interventions (Table 2). There are indications of good practice for the Kenyan milk, potatoes and vegetable categories. Kenyan bananas (17th protein rank, 8th DSQ rank, not shown in Table 2) also present protein fortification opportunities because the DSQ rank order is greater than the protein supply rank order. There are knowledge transfer opportunities for wheat supply chain management for both India and Kenya where wheat supply is a protein supply pressure point, and this is compounded by increased supply chain losses in India (Table 3).

The specific pressure points where food loss rank order (producer to retailer) in India are greater than the DSQ rank order are for potatoes, wheat, bananas, fruits, root crops and maize (Table 3). The sugar cane, milk, rice and vegetable categories show good practice in that food losses are equal to or less than that of the DSQ rank order for these categories. The pressure points for food losses in Kenya where losses are greater than the DSQ rank order is observed for most food categories with the maize and vegetable categories, indicating good practice (food loss rank order is lower than DSQ rank order) (Table 4). There are indications of good practice in that food losses are equal to or less than that of food loss rank for milk, cassava and wheat categories.

The Centreplate Model approach shown in Table 1 to Table 5 demonstrates where innovative NPD will be of greatest impact and identifies the protein diversity in Kenya and India is vastly different from that of the UK (Table 5). This is because the protein supplied by food sources is greater in quantity for the UK and the inclusion of increased livestock protein sources diversifies protein supplied. Table 1 and Table 2 indicate that developing diets that integrate vegetables and root crops with protein sources can improve protein supply because vegetable categories have favourable DSQ ranks and food loss ranks. This is not the case for the UK where vegetable losses are high and their contribution to protein supply relatively low (Table 5). The Centreplate Model indicates NPD processes that can integrate the use of vegetables as protein sources would be favoured in enhancing protein supply; this is not straightforward because such developments would require developing concentrated vegetable protein as ingredients that can fortify food products. Such programmes would require dehydration, milling and preservation technologies to be scaled to provide protein replacement in much the same way processed soybean products are manufactured.

The rank analysis has been developed as the Centreplate Model for dietary policy in the UK because it reflects the importance of protein portions of meals and it demonstrates food and protein security is not only concerned with volume of supply (Martindale, 2017a). The relative importance of protein supply with respect to domestic supply and food loss are critical in the model because it enables the identification of pressure points and opportunities in supply chain functions with respect to specific agri-food item categories. The importance of the protein content of foods is a major driver of dietary change and a decrease in the diversity of dietary protein is highlighted as a focus for improvement that can be achieved if innovative NPD strategies provide a wider range of products. The incentive for reducing food waste in the supply chain may well be provided by food processing and preservation because the development of new products (e.g. fruit juices) and stabiliser ingredients (e.g. maize starches) will enable waste reduction in supply chains from producer through to consumer functions. A critical component here is to understand how to unlock data held by the suppliers because this will stimulate changes to infrastructure and transport that are necessary for robust food security for food markets in India and Kenya. The requirement to diversify protein choice could be delivered by concentrating and stabilising vegetable proteins for ingredients so that they can be processed into foods and beverages. The ability to obtain more incisive supply chain data is a universal goal for improving protein supply and reducing food loss, and the interventions required to do this are summarised as a matrix in Table 6. The use of preservation techniques such as freezing and drying with storage interventions such as the use of fit-for-purpose packaging have been shown to result in less food waste in the UK (Martindale, 2014). The impact such waste reduction models have on NPD processes has also been tested for the UK food system and the research reported here indicates that similar approaches to food and beverage NPD could be utilised in India and Kenya.

Conclusion

The assessments of food systems for India, Kenya and the United Kingdom can use the GFSI approaches to identify knowledge transfer capacity, but food category focus provides further insight that relate to the potential to better preserve and store food categories. This can reduce supply chain losses and this study identifies critical points in food supply chain at which technological integration would be best utilised. The improvement of protein diversity is an action or challenge for food systems, which can be brought about by introducing new proteins into NPD processes for food and beverages. The approach is relevant for the UK food system where there are market developments to introduce greater amounts of plant proteins into diets. The Centreplate Model uses a protein and food loss ranking method that identifies protein supply pressure points and opportunities to develop fortified protein products using vegetables where production is not fully utilised for protein supply. Potatoes are a food category where there are increased supply chain losses, so tackling protein supply from this category with improved NPD is a target for reducing waste. Similar opportunities for improving the utilisation of potato product categories exist in the UK and for wheat product categories in Kenya, indicating an important area for future knowledge transfer. The Centreplate Model identifies these opportunities and challenges by using relative associations so that assessment is not just made with respect to volume of production as is the case for many sustainability and security assessments.

Data availability

Underlying data

The datasets used to develop this research and test the Centreplate Model were Food Supply – Crops, Livestock and Fish Primary Equivalent datasets for the most recent year (2013) obtained from the FAOSTAT databases publicly available at http://www.fao.org/faostat/.

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