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Global effects of food waste

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Abstract
A reduction in the loss and waste of human food is a global issue for poverty and hunger nations, and to reducing the agricultural area and water content. The food wasted by humans and it is mainly affecting to the wildlife ecology and behavior and community dynamics. The causes of food waste occur at the stages of producing, processing, retailing and consuming. Also, some other causes include lack of appropriate planning. The food waste causes some diseases and also pollution to the environment. In low-income countries, most loss occurs during production, while in developed countries 100 kg per person per year food is wasted at the consumption stage. Reasons for food waste include high quality standards, insufficient purchase planning, buying too much and cooking too much. Effects of global food waste include biodiversity loss, 250 Km^3 of water, 30% of worlds agricultural area can be wasted and the main effects of global food waste is global warming and greenhouse gas emission. The food waste to produce some positive effects includes biogas production and negative effects include hungry and food insecurity. In food industry to prepare more innovative products by using food waste materials. The wasted food can be converted into value added products and to increasing the nutritional value and to reducing the malnutrition percentage at global level. A solution for reducing the food waste includes prevention, optimization, recycling, recovery and disposal. The central and state governments to establish schemes and mobile apps to reduce food waste.

Keywords: Food waste, causes, effects, value added products, solutions, schemes.

Introduction
The European Commission defines food waste as fractions of food and inedible parts removed from the food supply chain that could had been recovered or disposed including crops that are not harvested, anaerobic digestion, bio energy production, co-generation and incineration (European Commission, 2016) [9]. Food waste is a social problem with far-reaching consequences, while the impact of food waste to global food security, socioeconomic and environmental consequences related to food production and waste of the food (Kibler *et al.*). Food waste requires attention at three levels, I) The individual unit of analysis, a focus on the behavior of consumers in response to regulatory incentives and self-motivated waste prevention actions, II) The local level, a focus on the governance mechanisms that may minimize food waste by residential, commercial and institutional actors III) Higher levels of governance, investments to large-scale application of technological advancements seeking to capture waste and extract alternative forms of energy and materials (Chaboud *et al.*).
The global food waste is related to global malnutrition. To estimate that 32% food can be produced for human consumption and it is wasted or lost at all the stages. When converted into calories, global food losses and waste amount to approximately 24% of all food intended for people. The half of all food grown is lost or wasted before and after it reaches the consumer (Parfitt *et al.*) Food waste prevention, situated at the top of the food waste hierarchy, is considered to be the most environmentally favorable management option. Every year, 1.3 billion tons of food produced for human consumption, a third of total production, is lost or wasted. Globally 1 in 8 people are lacking access to sufficient food, while land conversion to agriculture is arguably the single greatest threat to global biodiversity (Lipinski *et al.*).
T the European Commission (2016) [9], around 88 million tonnes of food are wasted annually in the EU, which constitute an estimated cost of 143 billion euros. Food waste means that the valuable and often scarce resources such as water, soil, and energy that were put in the production of that food are lost, and it also worsens climate change. According to FAO, the carbon footprint of global food waste is about 8% of all greenhouse gas emissions caused by humans. For every kilo of food produced, 4.5 kilos of CO2 are released into the atmosphere. Food waste also has ethical implications. According to the FAO, about 793 million people in the world are malnourished, while according to Euro stat, 55 million people (9.6%) were unable to afford a quality meal every second day in 2014 (European Commission, 2017).
Global Food Losses and Food Waste it estimates that a third of the food produced globally

every year for human consumption, approximately 1.3 billion tons, is lost or wasted (FAO 2011) [8]. Industrialized and developing countries lose almost the same amount of food, 670 and 630 million tons respectively (FAO 2011) [8]. The difference is that poor countries lose most at the start of the production and supply chain, whereas, in medium- and high-income countries, food is typically discarded while still suitable for human consumption (FAO 2011) [8].

2. The Political Economy of Food Waste

Food waste refers to the failure to use potentially edible items to satisfy human hunger, as well as to the inefficient use of plants, energy content and nutrients for human purposes. This assumes that food is for humans, reflecting the positioning and power of humans at the top of the food chain. Typically wastes are absent from research on food supply chains. Incorporating waste, however, requires recognition that wastes occur throughout the value chain and beyond into consumption and disposal (Alexander *et al*.) [2]

Recognizing that food waste arises in different locations and for different reasons, scholars and policy makers have provided different classifications and definitions of food waste. The commonest distinction is between food loss and food waste: losses refer to postharvest but pre-consumption waste, while waste only refers to wastes arising in the consumption stage. Food waste can result from excessively large portion sizes provided by the food industry, especially if the food spoils quickly after the packaging has been opened (Hirsch *et al.*)

3. Food waste background

3.1. Food loss and waste definitions

Definitions of food loss and food waste items removed from the food supply chain during pre- and post-consumer phases Xue *et al*. Food loss encompasses any decrease in quantity or quality of food through the food supply chain, for any reason. Food waste is a subset of food loss, and consists of material intended for human consumption that is not consumed. Food loss and waste have traditionally been differentiated based on the level at which edible food was removed from the supply chain, with food losses occurring earlier in the supply chain and food waste occurring in later stages (Parfitt *et al.*, 2010) [17].

3.2. Scale of the food waste problem

According to FAO (2011) [8] the available evidence suggests that food loss and waste represent a considerable portion of the global food supply, roughly one-third of food produced globally by weight, or one of every four kilocalories produced Silvennoinen *et al.* [8] found that in the Finnish food service system, around 20% of food served is wasted just in the processes of preparation and handling Betz *et al.* estimated that storage, preparation, and serving losses, combined with plate waste in Switzerland, totaled around 18% of food grown. In the United States, food waste generation is estimated at approximately 0.28 kg/person/day Thyberg *et al.* or approximately 31% (by weight) of food available at retail and consumer levels Buzby *et al.*

4. Legal Framework for food waste

The legal framework of the EU on food waste is complex and it covers various areas of the value-chain of food. The legislative acts concern the issues regarding food waste generation, management, reduction, food use optimization and legislation with more than one implication for food waste. Food waste is caused, on the one hand by the complexity and over-regulation of certain areas of the food chain and on the other hand by the complete lack of rules in other sectors.

Directive on waste, known as the Waste Framework Directive, sets the basis of waste management principles and it imposes to each Microsoft to include food waste prevention into their general waste prevention programmes. It requires waste to be managed without endangering human health and harming the environment, and in particular without creating risk for water, air, soil, plants or animals. Moreover, it should not cause any nuisance through noise or odours, and should not adversely affect the countryside or other places of special interest. The Directive introduces a waste management hierarchy that has to be adopted by each Microsoft. This hierarchy has five stages: prevention, preparing for reuse, recycling, recovery and disposal. This policy brief mainly focuses on the prevention stage, which is the basis to foster a concrete and radical change in food waste behavior (European Commission, 2008) [8].

The Waste Directive in articles 2(1)(f) and 3(4)(a) and General Food Law in article 2 provide the definition of food waste means whether processed, partial processed or unprocessed, intended to be or reasonably expected to be ingested by humans, that is not being used and as a result is wasted.

5. Causes of food waste

The roots of the problem of food waste are complex and wide-ranging. The agricultural sector must meet the demands of the retail sector, whereby this reflects consumer preferences and demands which are typically high, as a variety and abundance of food is generally the expectation of consumers. The retail sector responds to this by ensuring a certain margin of security, thereby a certain amount of overproduction by farming is common. Occasionally this can lead to the cancellation of orders from the retail sector dropping the burden of cost onto the agricultural sector. The unwanted food does not reach consumers and thus becomes waste. This occurs due to unfair trading policies and out-grading of irregular fruit and vegetables.

A lack of a universal measuring system that accurately collects data on food waste at all levels of the food supply chain could be contributing to the food waste issue. The scope of the food going to waste is likely underestimated, considering food waste is occurring at all levels of the FSC and data so far is based on small scale models of food waste. In addition, food lost at the harvesting stage is not considered to be waste and is currently not measured at all. This lack of a common data collection system creates additional problems which can exacerbate the scope of food waste, such as not knowing where to implement best strategies along the food waste pyramid, as well as not accurately knowing whether the funding for these strategies has been put to good use. 53% of food waste occurs at the household or consumer level (European Commission, 2016) [9]. This is partially due to a lack of education and information, consumer preferences and a lack of awareness.

Europe-wide, there is a lack of understanding by consumers on the “best before” and “use by” food shelf-life dates. This leads to food being thrown away unnecessarily while it is still good to consume. Similarly, consumers may lack the required input for how to use leftovers and/or use the whole food (vegetable/fruit). Food banks and start-up ideas such as discounted regional food or meals which can be found over an *apt* to be picked up by the consumer are relatively new, and

so the awareness of their existence is lacking. Over-availability of food in Europe has increasingly fuelled consumers' expectations on food availability in the past decades. This may be contributing to a lack of awareness of the resources and time required to produce food, as well as the lengthy process food goes through the FSC, thereby an awareness of the scope of the problem of food waste is lacking. In addition, consumers prefer "good- looking" or "normal" fruit and vegetables, leading to out-grading at consumer but also retail level.

5.1. Lack of appropriate planning
One of the top contributors to food wastage is because of lack of appropriate planning on the consumer part. Sometimes people buy lots of food without appropriately making plans on when and how the food will be prepared for consumption. Coupled with the contemporary schedules of work and appointments, people therefore tend to change food preparation plans or fail to remember using it on time. At times it's out of most people's control which leads to expiry of the foods after which they are thrown as waste. Also due to lack of appropriate planning, people find themselves having badly prepared food that just doesn't taste great. It all ends up as waste.

5.2. Purchase and preparation of too much food
Most of the time, food is also wasted because of purchasing or preparing too much. If one purchases or prepares too much food than is needed, then it's obvious the excess food on the plate will go to waste. In such scenarios, leftovers and partially used food account for the food that goes to waste. Alternatively, the partially used food is at times put at the back of the fridge and is never reused. The same applies to excess purchases that end up passing their expiration dates and therefore looks, tastes, and smells bad. At the end of it all, all the excess ends up as waste food.

5.3. Errors in industrial processing and keeping up with food safety policies
Another biggest driving factor for food wastage is the protocol on food safety. The food safety protocols give no room for error in industrial processing or any other compromise that diminish quality of the final food products. As such, the confusions and errors during industrial processing of food mean that all food items that don't meet the set standards are wasted. Food processing companies have to comply with high food safety regulations and must thus establish no error margins. In complying with the food safety policies, the companies in the sector end up creating waste as any small error means the food will be rejected even if it's simply due to imperfection in appearance or shape. Overcooking, production trials, packaging defects, trial runs, and wrong sizes and weights are some of the aspects resulting in imperfection and the eventual rejection of the foods.

5.4. Managerial, financial and technical constrains
This is mainly a challenge contributing to food wastage in the developing countries. The wastage takes place because of the constraints to do with lack proper management, inadequate finances, and technical difficulties in the lines of harvesting methods, storage and cooling problems in adverse weather conditions, processing, packaging, infrastructure, and marketing systems.

5.5. Over-preparation of food in restaurants, hotels and the food service industry
Most restaurants, hotels and the food service industry alike have a tendency of over-preparing/producing food. While the intention is good especially in anticipation of high customer volume and the ability of not running out of menu, over-preparation often leads to wastage if all the food is unsold. DC Central Kitchen–committed to the course of reducing food wastage, points out that overproduction in the food service industry is the leading cause of food wastage. Since the food service operations lacks the ability to quantify the amount of food consumed on average, the kitchens keep producing amounts thought to be enough but most of it is actually not needed. Besides, some managers believe producing food in large batches minimizes on costs, but in actual fact it results in more waste as compared to cook-to-order preparation or cooking in small batches.

5.6. Over-merchandizing and over-ordering in food stores and supermarkets
The over-merchandizing of food items and products in retail centers, wholesale markets, and supermarkets often result in food wastage. Foodservice operations are habitually more focused on over-merchandizing in food stores and supermarkets by using beautiful and attractive displays thereby creating the idea of abundance in an attempt to promote sales and customer satisfaction. The overlooked aspect of over-merchandizing is its association with increased food waste. When people buy more than needed, the excess will often end up in the trash bin. Over-ordering also leads to expiry of food staff with limited shelf life as some of it will remain unsold.

5.7. Consumer behavior
Different customers have different preferences and this highly influences consumer purchasing behavior on food items. Particularly, the consumer behavior on focus here is the tendency of having a keen insight for good judgment which results in those who only prefer unblemished vegetables and fruits, and the restrictive must display for shelf life dates. Such consumer behavior more often than not contributes to the wastage of food as most of the food items may remain on the shelves till expiry. Also, such consumer behavior tendencies may force foodservice operators in restaurants and hotels to maintain large menu options and high-end services while assuring consistency that mostly leads to food wastage.

6. Consequences of food waste
The consequences of the problem are equally complex. As already outlined, food waste places an enormous burden on the economy. For 2007, the FAO estimated the value of the global food wastage at USD 750 billion (FAO, 2013) [11]. This economic loss occurs at all stages of the food supply chain, affecting producers and retailers, but also consumers.

Next to the economic consequences, wasting food impacts the environment in several ways. According to the European Commission, the food sector causes approximately 22% of the global warming potential in the EU (European Commission, 2006). If food loss and waste were a country, it would be the third largest greenhouse gas (GHG) emitter in the world. Additionally, expanding areas for production of increasing amounts of food leads to an alarming rise of exploited resources Papargyropoulou *et al*. Tragically, the FAO mentions the loss of biodiversity is occurring as an indirect consequence of food waste (FAO, 2013) [11]. At the same time, land that is currently used to compensate food losses,

could be used for a variety of other purposes. According to the FAO, the total amount of food waste occupies almost 1,4 billion hectares (28%) of the world's agricultural land area (FAO, 2013) [11]. Thus, reducing food waste would also offer the possibility to

a) Shift farming towards a less intensive and more sustainable way and

b) Meet the demand of a growing world population.

In addition to its economic and environmental impact, wasting food is also associated with social consequences. Minimizing food waste is not only economically advantageous and reduces the exploitation of resources; but rather it is also a crucial step towards achieving worldwide food security. Thus, food waste also has an ethical and moral dimension Papargyropoulou *et al*.

7. Global food waste

7.1. Food Wastage in Developed Nations

The developed nations grow their food in massive quantities due to the high subsidies and flood the market with their produce. With the overflow of the produce, the excess is kept in warehouses. If the food is kept for long-time in these warehouses, decays, therefore, are reducing the eatable food. This is further reduced due to the consumer buying pattern and their obsession with aesthetic quality of food. Vegetables & fruits aside from being healthy tend to wilt, brown, bruise or discolor; this is something the consumers do not prefer to buy. Due to this buying pattern and thinking of the consumers, even grocers refuse to stock such imperfect looking food on their shelves or stands. In Europe & North America, the per capita waste by a single consumer is between 95-115 kg a year. The industrialized countries exhaust 670 million tonnes of food worth. If the food currently wasted in Europe and North America is to be fed to people then it could feed 200 and 300 million individuals respectively Nigam *et al.*

7.2. Food Wastage in Developing Nations

It is not just the industrialized nations that have a high percentage of food wastage, but now the developing nations are also closing unto these numbers. This primarily takes place due to the poor infrastructure, dysfunctional distribution systems, and corruption. More than half of the produce in these countries doesn't reach the market and even less to the people who reside there. This is causing a loss of billions; children and adults are micronutrient undernourished, and blighting numerous lives. Wastage of food not only has a negative impact on the individuals of the nations but the economy and the environment. Economically, it is a waste of an investment which can reduce the income of a farmer and increase a consumer's expenses. Environmentally, the impact includes excessive emission of greenhouse gases, extensive & inefficient use of water, and minerals thus diminishing the natural ecosystem which we live in. In these nations, the wastage occurs at early stages of the chain and they can be traced back to the financial, managerial and technical constraints during harvest and the basic problem of storage and cooling units. These countries dissipate 630 million tons of food. In sub- Saharan Africa, south & south-eastern Asia, the per capita waste by a single consumer is between 6-11 kg a year. In developed nations, more than 40% losses transpire at the consumer and retail levels, while in the developing nations 40% of the losses transpire at post-harvest and processing levels. These losses that take place during harvest and storage converts into lost income for the farmers and high food prices for the consumers Nigam *et al.*

7.3. Food Wastage in India

In a CSR Journal report, it stated that "Indians waste as much food as the whole of United Kingdom consumes." With over 1.3 billion people in a nation like India, millions are still sleeping hungry. In the Global Hungry Index - 2017, India ranks 100 among the 119 countries. Food wastage not only represents hunger, climate change or pollution, but also various glitches in the nation's economy, like inflation. Our traditions and culture play one of the major roles in these situations where the policies of the government aren't responsible for such wastages. Here in India, the bigger the wedding, the bigger is the food wastage is expected to be. Today the numbers of individuals who are 119 hungry in Indian are now more than 65 million, which is statistically higher than the population of few countries in the world. Wastage of food can cripple a nation's economy to such an extent that most of us are uninformed. Despite India's largest livelihood being agriculture, there is a struggle to feed its ever-growing population. Regardless of this fact, we are able to grow enough produce to feed each individual but this adequate production of food doesn't guarantee India's food security. As India is a developing nation 40% of our produce is lost during post-harvesting and processing level. India suffers losses of up to £4.4billion in fruit and vegetables each year due to the absence of effective technologies to keep produce cool. A United Nations report states that India is ahead of China when it comes to wasting food items and both of these nations are the worst culprit of food wastage. An estimate of 230 cubic km of fresh water goes into producing food which is eventually wasted, this water is enough to quench the thirst of 10 crore people each year Stancu *et al.*

8. Effects of food waste

8.1. Biodiversity loss

Food wastage impacts on biodiversity loss at a global level. In order to maximize agricultural yields, farmers have increasingly invaded wild areas in search for more fertile lands which has led to loss of biodiversity. The reason for this is that practices such as slash and burn, deforestation, and conversion of wild areas into farm lands have destroyed the natural habitats for birds, fish, mammals and amphibians. Agricultural practices such as mono-cropping have also compounded biodiversity loss. The mass rearing of livestock for consumption and the use of pesticides in crop production has also significantly contributed to nitrogen, phosphorous, and chemical pollution in streams, rivers and coastal waters thus affecting marine life.

8.2. Wastage of the 1/3 of the world fertile land areas

According to research, the produced but unconsumed food accounts for approximately 1.4 billion hectares of land, constituting almost 1/3 of the planet's agricultural land. By looking at this from a well thought analytical angle, the world is wasting 30 percent of the world's fertile land which could be used for other meaningful purposes such as environmental research.

8.3. Blue water footprint

The volume of water used in agricultural food production is immense. Therefore, if 30 percent of all the food produced goes to waste, then it means that more than 30 percent of freshwater used in the production and processing of food also goes to waste. This contributes to blue water footprint which refers to the amount of consumed surface and groundwater resources that goes to waste. Precise estimations indicate that

food wastage is responsible for the wastage of nearly 250 cubic kilometers (km3) of water. This wastage is equivalent to thrice the volume of Lake Geneva. It is also affirmed that throwing out a kilogram of beef amounts to a waste of 50,000 liters of water used in the meat production process. Similarly, 1000 liters of water is wasted if one glass of milk is poured down the drain.

8.4. Increased carbon footprint and the acceleration of climate change

The food produced and then later goes to waste is estimated to be equivalent to 3.3 billion tons of greenhouse gas emission, accelerating the impacts of climate change. Research also has it that food waste is the third biggest emitter of greenhouse gases. The reason for this is the consideration for the energy wasted and the primary use of fossil fuels in food production including processing and cooking together with transportation to various consumer markets worldwide. What's more, the methane gas produced at landfills by food thrown out as waste further aggravates climate change and global warming.

8.5. Economic consequences

In addition to the environmental impacts, food wastage also results in direct economic costs. According to FAO's report estimates, the economic losses associated with food wastage is about $750 billion dollars per annum.

9. Direct Effects on Wildlife Ecology and Behaviour

In addition to changes in dietary preferences, the distribution and quantity of food waste is likely to influence the carrying capacity, behaviour, and habitat use of wildlife. The Resource Dispersion Hypothesis (RDH) provides an obvious theoretical basis for predicting some of the likely outcomes, at least with respect to territory size and group size. The RDH predicts that the spatial dispersion food patches determine territory size, whereas patch richness dictates group size. Thus, where there is an abundant food source at a focal location, wildlife may congregate and focus their daily activities around this food source and have larger group sizes Thompson *et al.*

In the case of dingoes, access to large quantities of food scraps at a waste facility resulted in decreased home-ranges and movements, larger group sizes, increased rates of inbreeding and changes to their sociality and habitat use. In the case of bears, the closure of dumps in Yellowstone National Park in the 1970s led to rapidly increased grizzly bear mortality and a more than fivefold increase in home range areas. Similar effects have been found for black bears, but higher fecundity recorded in urban areas was counter-balanced by high human-caused mortality. High bear mortality by vehicle collisions has been specifically linked with bears attraction to garbage Thompson *et al.*

10. Indirect Effects on Other Species and Ecological Communities

The predictability of food waste as a resource can trigger population increases of opportunistic species, in turn altering predator-predator and predator-prey dynamics. For example, abundant food supplies can change the interactions between individuals, including bears tolerating other bears around rubbish dumps. The removal of an anthropogenic food source can alter predator-prey dynamics, as in the case of spotted hyenas, who increased predation on domestic donkeys during Christian fasting periods when food waste was limited. Increasing food waste availability can have a similar effect; for instance, overfishing and increasing waste in landfills have changed the resource base of coastal food webs, and generalist seabirds like western gulls have responded by shifting their diet to human trash, but at the same time, they increased predation pressure on a threatened species of fish. Increased interactions between species at food waste sources may lead to increased hybridization both among wild species and between wild canids and their domestic relatives Thompson *et al.*

11. Solutions for food waste

11.1. Balancing food production with demand

Foremost, precedence should be centered on balancing food production with demand to reduce the problem of food wastage. The first thing is to cut back on the use of natural resources in food production. In hotels, restaurants and the food service industry, risk management tools can be applied. Such a tool will work towards ensuring managers and chefs only produce and cook food in accordance with demand or the orders made. Producing large batches of food has always resulted in food wastage. So in trying to save food, labor and money, hotels and the entire food service industry should work on the production of small batches or use the cook-to-order option.

11.2. Bettering food harvesting, storage, processing and distribution processes

The second strategy should be placed on developing efficient technologies and production systems that better storage, harvesting, processing and the distribution processes. Redistribution can be the initial strategy for supplying or distributing more food to where there is need and reducing supply where food is in surplus. Harvesting, storage and processing should also be improved by governments and NGOs by availing subsidies and training on better production practice, especially in developing countries.

11.3. Food waste reduction initiatives

Supermarkets, retail food outlets, big restaurants and individual consumers all alike can also work on their own tailored and creative efforts to reduce food footprint. For instance, individual consumers can cut back their food footprint by not necessarily placing high preference on the very best food quality. At times even the ugly or blemished food items is still edible or can be purchased then used to make dishes like soups. Over-merchandizing can also be reduced to minimize food wastage.

11.4. Consumers to buy and prepare food with a plan

The use of meal plans in preparing food can go a long way in ending food wastage. Consumers should only buy food according to their plans or in small batches to reduce the food that goes to waste due to expiration after long storage periods.

11.5. Food recycling

Food recycling efforts are already underway but the technologies and methods used should be bettered. Starch-rich foodstuff such as crisps, bread, biscuits and breakfast cereals can for instance be recycled into high quality feeds for livestock. The recycling of the food packaging materials can equally reduce over-exploitation of virgin material. If it's completely unfit for consumption, it can still be converted for other uses instead of being taken to the landfills to emit methane gas.

11.6. Food print campaigns

Campaigns for reducing food footprint can help fishers, farmers, supermarkets, food processors, individual consumers, and the local and national governments to work on strategies for preventing food wastage. The UN and FAO have already launched such a campaign by putting emphasis on "Think Eat save – Reduce Your Food print" campaign slogan. Moreover, with more and more of such campaigns, societies at large will be informed on ways for reducing food print and get the real facts about environmental impacts. Ultimately, it will aid in solving the problem of food wastage.

12. Food products made from food waste

- Beer, brewed from old bread
- Healthy snacks, made from brewery waste - super grain bars
- Ugly fruits turned into yummy drinks
- Preserving the glut, again
- Direct consumer sales of aesthetically challenged produce
- Soup from surplus

Table 1: Food waste by products

Food product	Waste stream	Current management
Ales, lagers & spirits	Spent grains, distillers' dark grain & draff	Animal feed, composting, anaerobic digestion
Apples	Pomace	Production of animal feed
Cheese	Whey, whey concentrate and whey permeate	Production of foodstuffs (whey powder, demineralised whey, lactose, Ricotta cheese, cream), production of animal feed, production of fertilizer, production of microbial culture medium, fermentation and anaerobic digestion, transformation to peptides and glucose
Vegetable oil	Olive stones	Production of fuels, industrial uses (kernel oil, wood, activated carbon)
Cider	Pomace	Animal feed, anaerobic digestion
Eggs	Egg shell waste (shell)	Source of calcium for use in animal feed and pet food, land spreading, filler for use in plastics, other potential uses under investigation
Lamb, beef, pork & poultry	Blood	Production of foodstuffs (raw, plasma, albumin), production of pharmaceuticals, plants, production of animal feed (blood meal, raw, albumin), anaerobic digestion
Lamb, beef, pork & poultry	Bones	Production of animal feed production of chemicals (glue, detergent), production of foodstuffs / pharmaceuticals (gelatin), composting, anaerobic digestion, production of low gel, low viscosity products
Lamb, beef, pork & poultry	Hair, feathers, hooves & feet	Production of chemicals (glue, gelatin, collagen, glycerin, soap), production of pharmaceuticals (Ca, P, gelatin, collagen, fat, insulin, heparin, pepsin, steroids, cholesterol), production of animal feed production of foodstuffs (sausage casing, catalase, additives), anaerobic digestion, composting, production of feather meal (animal feed and fertilizer), production of pillows & eiderdown
Vegetable oil & margarine	Crude & extracted press cake or spent meal	Production of fuels, industrial uses (kernel oil, wood, activated carbon)
Wheat milling products	Wheat feed / wheat middling's	Feed for use by cattle, sheep and pigs
Lamb, beef, pork & poultry	White and red offalincl guts & giblets	Production of chemicals (glue, gelatin, collagen, glycerin, soap), production of pharmaceuticals (Ca, P, gelatin, collagen, fat, insulin, heparin, pepsin, steroids, cholesterol), production of animal feed (meat meal, fat), production of foodstuffs (sausage casing, catalase, additives), anaerobic digestion
Light wines	Pomace (skin and seeds)	Production of ethanol, extraction of antioxidants & pigments, production of grapeseed oil (cooking oil & beauty ingredient) & grapeseed flour (food ingredient), production of resveratrol, production of bio-based packaging
Oranges	Citrus zest, peel, seed, membrane residue after juice extraction	Cattle feed
Potatoes	Fibre, concentrated fruit juice & protein from potato starch production	Protein extraction, production of animal feed
Potatoes	Peelings	May be used directly as potato feed or combined with potato puree to give potato puree feed
Spirits	Organic wastes, mash from grain, fruit or potato	Animal feed, composting
Sugar	Sugar beet pulp	Marketed in fresh / ensiled form as pressed pulp or blended with molasses to give molasses sugar beet feed (MSBF)
Tomatoes	Pomace (skin, pulp & seeds)	Animal feed

13. Schemes adopted to reduce wastage

13.1. Mega food parks

The scheme aims to link agricultural production to markets by using a cluster approach, implemented by an SPV. It supports the creation of infrastructure for setting up of modern food processing units in the park and connecting it with a well-established supply chain. The scheme provides a capital grant of 50-75%, subject to a maximum of $7.15 Mn per project. Till March 2019, 42 such parks were under various stages of implementation.

13.2. Cold chain, value addition and preservation infra

The scheme aims to provide integrated cold chain and preservation infrastructure facilities along the entire supply chain of food processing. It covers Minimal Processing Centre having weighing, sorting, grading, packing, storage

and quick-freezing facilities. Grant-in-aid, up to a maximum of $1.43 Mn, is provided for 35% - 50% storage infrastructure and transport infrastructure and 50-75% value addition and processing infrastructure. Until March 2019, 299 approved cold chain projects were under various stages of implementation.

13.3. Creation of food processing and preservation capacities

The scheme aims to create and modernize processing and preservation capacities by increasing the level of processing and value addition, leading to a reduction in wastage. Under the scheme, a capital grant of 35-50%, subject to a maximum of $0.71 Mn per project, is provided. Till December 2018, 134 projects were approved under this scheme.

13.4. Creation of backward and forward linkages

The scheme aims to provide effective and seamless backward and forward integration in the processed food industry. Financial assistance is provided for setting up primary processing centers, collection centers and modern retail outlets. This is supplemented with connectivity through insulated or refrigerated transport. The scheme provides a capital grant of 35-50%, subject to a maximum of $0.71 Mn per project. Till December 2018, 70 projects were approved under this scheme.

13.5. Food safety and quality assurance infra

The scheme aims to make India's food and agro-processing sector have a competitive edge in the market by creating infrastructure for safety and quality assurance services. Under this scheme, the government extends financial assistance of 50-70% for the cost of laboratory equipment and 25-33% for civil work and 50-75% reimbursement for HACCP/ ISO Standards/Food Safety/Quality Management Systems. Till November 2018, 76 Food Testing labs were instituted under the scheme.

13.6. Agro processing cluster

The scheme aims at cluster approach-based development of modern infrastructure and common facilities to encourage a group of entrepreneurs to set up food processing units. The scheme provides grants-in-aid of 35-50% of eligible project cost, up to a maximum of $1.43 Mn per project. Till December 2018, 33 projects were approved under the scheme.

14. Six High-tech solutions to food waste

14.1. LeanPath

The Portland, Oregon-based software firm developed a program that allows restaurants and institutional food service providers like hospitals and universities to track the amount of food being tossed out and use the data to adapt their processes to reduce waste. Clients like ARAMARK, MGM Resorts and Sodexo use scales to weigh waste and touch screen terminals to document the source of waste, including spoilage and over-production. The info is stored in the cloud where LeanPath accesses it for analysis and provides reports that help users make changes like adjusting standing food orders or rotating foods in walk-ins. To date, users have reduced food waste up to 80 percent.

14.2. Spoiler Alert

A team of MBA students at Massachusetts Institute of Technology created a program that allows users like supermarkets and restaurants with excess food to post details about what is available and send it out to a network of recipients, including food pantries, that can use the food (and keep it from the landfill). The mobile and web-based platform gives users the option to conduct transactions via donations, discounted food sales and waste recovery opportunities (like coffee grounds for compost or vegetable oil for biodiesel). A pilot program launched in Boston and is ramping up for wide release this summer.

14.3. Local Roots

The perishable nature of food means there is a limited window to find a place to sell or donate excess food before it goes bad. A new app developed by Atlanta-based business, Local Roots, helps farmers and food artisans connect with shoppers interested in purchasing local food. Much like other shopping interfaces, the Local Roots app uses location data to generate a list of available products, purchase goods and schedule pick-up or delivery. How does a shopping app reduce food waste? According to creators,

local farmers and food producers often struggle to connect with buyers; the app creates new opportunities to bring them together, reducing the amount of fresh food that spoils because it's unsold.

14.4. Eco-Safe Digester

BioHitech America created a device that uses heat, moisture and oxygen to break down food into water in the food service facilities of companies like Amazon, General Electric and Marriott. The onsite digester sends wastewater through the sewer lines to water treatment facilities. Turning wasted food into wastewater doesn't eliminate food waste, which is the reason the digester incorporates Big Data, allowing users to record details about the waste. Using the analytics, BioHitech America generates comprehensive reports that allow users to identify (and rectify) operational inefficiencies. To date, the technology has helped divert 50 million pounds of food waste from the landfill.

14.5. Food Keeper

A lot of food is tossed over safety concerns, including questions about when leftovers spoil or if you can drink milk past its expiration date. To help educate consumers and keep edible foods from going to the landfill Cornell University developed an app with a searchable database of more than 500 foods, including cooking tips, food storage advice and info about expiration labels. The app will even sync with your smartphone and issue alerts when food expiration dates near. Through a partnership with USDA, the app offers a 24-hour virtual hotline (called "Ask Karen") for real time answers to food storage questions.

14.6. FareShare FoodCloud

In the UK, grocer Tesco created an app that sends alerts to partner charities (FareShare and FoodCloud) about surplus food that is edible but at risk of being dumped. The charities use the app to confirm they want the food, which is offered free of charge, and arrange to pick it up and turn it into meals that are distributed through organizations like homeless shelters and school breakfast programs. Tesco estimates that 30,000 tons of the food that its stores threw out last year could have been eaten. The goal of the app is to reduce that number by getting into the hands of charities that can immediately put

it to good use. In Ireland alone, 300 charities have collected and redistributed food using the app.

15. The conventional food waste management technologies

15.1. Incineration

Incineration is one of the most commonly used technologies for FW management worldwide. For example, in Singapore, 809, 800 tonnes of FW were generated in 2017, and roughly 84% of which were incinerated for volume reduction, with the incineration ashes residue being landfilled. Similar situations have also been observed in China and Malaysia (Liu, 2014; Ong *et al*., 2018) [17, 20]. Incineration is a process of releasing heat energy through burning the mixed FW with additional fuels at 800–1000 °C. Complete killing of pathogenic microbes and up to 90% of the volume reduction are achievable through incineration of FW Pham *et al* [16]. Besides, it should be noted that the incineration of FW also has obvious disadvantages of lower caloric value of raw FW, high capital and operation costs and generation of harmful and greenhouse gases. For the purposes of illustration, if global FW (i.e.1.6 billion tons) was all incinerated, about 586 million tons of CO2 would be generated and ultimately entered the atmosphere assuming 20% of total solid content in FW and 50% of carbon content in dry FW. Moreover, it had been reported that about 70 kWh of electric energy was required for incineration of one ton of wet FW in a typical incinerator, and 0.2 ton of ashes residue could be generated from incineration of one ton of dry FW Knorr *et al.* [17]. These suggest that the incineration of FW cannot be considered as an environmentally friendly process due to its high energy demand, production of incineration ashes and generation of harmful and greenhouse gases. Going forward, the incineration-based urban solid management may be challenged in view of its environmental and economic sustainability.

15.2. Landfill

Landfill is the oldest disposal process of FW, in which FW together with other municipal solid wastes are buried into natural or artificial pits and subsequently degraded by microbes (Thi *et al*., 2015) [31]. In general, landfill has the advantages of easy operation and management, low capital and operation costs, large disposal capacity etc. However, it should be pointed out that landfilling of FW has some inevitable drawbacks of (1) generation of large amount of leachate with heavy metals and pathogenic bacteria; (2) difficulty in mechanical compression; (3) poor sanitation; (4) large footprint and (5) production of methane, causing the concerns on field safety. Currently, landfill has been gradually phased out in more and more countries because of the land restriction and environmental impacts. For instance, the fraction of FW land-filled was reduced from 81% in 1994 to 20% in 2008, while now such practice has been banned in South Korean. Similar trends have also been observed in European Union, United States, Japan etc. Kibler *et al.*

15.3. Aerobic composting

Aerobic composting is a process engaging aerobic microorganisms (e.g. bacteria, actinomycetes and fungus) to decompose organic matter in FW to compost under aerobic conditions. FW with abundant organic matters and nutrients (e.g. nitrogen, phosphorus and potassium) can serve as an excellent feedstock for aerobic composting. In fact, aerobic composting has many advantages of easy operation, low cost and effective nutrient recovery. Currently, industrial-scale composting of FW has been widely practiced as a management measure in many countries. However, it should be realized that high water content, salinity and oils of FW makes aerobic composting of FW environmentally unsustainable due to the generation of various secondary pollutants. Moreover, aerobic composting needs longer retention time of weeks and large land footprint, while generating nuisance leachate and odors. It appears obvious that aerobic composting could not be considered as a feasible solution of food waste management in highly urbanized cities.

15.4. Anaerobic digestion

Anaerobic digestion has been applied for FW treatment with the aims for energy recovery and volume reduction Xu *et al.* It has been known that anaerobic digestion is limited by low hydrolysis efficiency of FW, thus only about 40–60% of volatile solids in FW can be degraded and eventually converted to biogas, while generating a substantial amount of residual solids which obviously need further disposal Zhao *et al.* To improve anaerobic digestion efficiency, co-digestion of FW with other organic feedstocks (e.g. animal dung, crop straw and activated sludge) had been explored Li *et al*. with about 30–40% of the solid residue being produced for further disposal. Evidence shows that digested solid residue is unsuitable for agricultural uses. Recently, Ma *et al*. (2017b) [19] developed a novel co-digestion process of activated sludge and FW for concurrent production of biomethane and biofertilizer. It was found that the heavy metals contents in the solid residue produced from anaerobic co-digestion exceeded the limits set by Chinese National Standard for Fertilizer, indicating that such solid residue could not be readily used for agriculture. Currently, the digestate produced from anaerobic digestion has been banned for agricultural uses in more and more countries. Thus, the solid residues from anaerobic digestion should be further handled in a proper manner, e.g. incineration or landfill. Meanwhile, it should also be noted that the valuable resources in FW (e.g. nitrogen & phosphorus) cannot be efficiently recovered through anaerobic digestion. Therefore, anaerobic digestion of FW, to some extent, is against the current concept and practice of circular economy which indeed is the way to shape the future FW management.

15.5. Animal feed

FW rich in nutrients, starch, cellulose, lipid, protein, minerals and trace elements had been explored as a suitable raw organic material for producing multi-functional protein feeds known as dehydrated feed and biochemical feed feed (San Martin *et al.*, 2016) [28]. Dehydrated feed is produced mainly through wet hot or dry hot physical treatment of FW with the concurrent drying and sterilization. However, applied temperature in this process may not be high enough to completely deactivate all pathogens in FW. For instance, the prion responsible for the mad cow disease cannot be totally deactivated even by the high-pressure steam of 134–138 °C. On the other hand, biochemical feed is basically produced from pretreatment and fermentation processes of FW, in which FW is subjected to crushing, screening, dehydration and drying, followed by addition of probiotics for transforming macromolecular organics into absorbable small molecular organics through solid state fermentation. Consequently, the produced amino acids and proteins start to gradually accumulate in the feed via the proliferation of single cells (San Martin *et al*., 2016) [28]. Although fermented feed has the advantages of low cost, high mechanization degree and high

resource utilization rate, protein feed produced from FW may cause the protein homology which may lead to the potential spreading of various diseases (e.g. mad cow disease, scrapie etc.), while posing a serious concern on public health and a threat to animal farming Salemdeeb *et al*. Currently, direct use of untreated FW as the animal feed has been legislated in many countries, e.g. the United States and Canada etc. Salemdeeb *et al*. More seriously, the European Union has banned all FW-based feeds to reenter the human food production chain, while the Chinese Animal Industry Act has also clearly articulated that FW prior to high temperature treatment is not allowed to be used as animal feed.

15.6. Bioethanol fermentation

Bioethanol demand and price both stand on a rising trend partially due to increasing price of commercial gasoline. For example, In China, the price of Number 93 gasoline had jumped from CNY3750/ton in 2005 to CNY6200/ton in 2016. In practice, bioethanol is often blended with gasoline to partially replace fossil fuel because of its combustibility and density Ma *et al.* [22]. Nowadays, more than 40 countries have allowed uses of biofuel-ethanol and automotive ethanolgasoline, with the annual consumption of about 600 million tons of bioethanol which accounts for about 60% of global gasoline consumption. In many countries, corn and sugar crops have been commonly explored as feedstocks for bioethanol production. Due to many obvious reasons, this approach is not economically viable and environmentally sustainable. Therefore, it is necessary to develop alternative, green and sustainable feedstocks for bioethanol production towards environmental and economic sustainability. Given such a situation, FW rich in carbohydrate has been demonstrated to be an excellent feedstock for bioethanol production through aerobic or anaerobic fermentation. For example, bioethanol with the concentration of 58 g/L was produced from FW, but about 30–40% of solid residue after FW fermentation still needed to be disposed of Slorach *et al*. reported an innovative approach for bioethanol production from FW through pretreatment with in-situ produced hydrolytic enzymes, known as fungal mash. By adopting this innovative approach, a higher bioethanol concentration of 71.8 g/L was produced concurrently with about 90% total volume reduction of FW. However, even at such a high bioethanol concentration, the post-concentration and purification are definitely needed to meet various commercial requirements. These in turn make the whole process rather complex and highly energy intensive. Moreover, it should also be realized that a large amount of residual liquid with the total COD of 20,000–50,000 mg/L could be generated from bioethanol concentrating process, and this, without doubt, challenges the process sustainability. Thus, it seems that the fermentation of food waste towards bioethanol production could not provide a green solution for future FW management.

Conclusion

In this study, the global to waste more amount of food and the wasted food to be converted into by products. To reducing the food waste by using different methods such as anaerobic digestion, landfill, incineration and bioethanol fermentation. In some areas the wasted food used as a animal feed. The food waste can create more number of disease and malnutrition. Nowadays the food waste can be reduced through mobile apps and some other technologies. In our government to provide more facilities to reducing the food waste.

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