



Food Loss and Food Waste: Economic Implications, Environmental Consequences, Sustainable Solutions for Management with Respect to Developing Nations

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Abstract: Food loss (FL) is the term which can be defined as "the decrease in quantity or quality of food that makes it unsuitable for human consumption" by the United Nation's organisation FAO. Food wastage is a major component of food loss and infers to food products that are discarded at the consumer and retailing level. According to the FAO of the United Nations, amount of lost or wasted food that is present in the supply chain is estimated at 1.35 billion tonnes per year that was being produced for the consumption of human beings but was not consumed. According to calculations made by the Boston Consulting Group (BCG), the quantity of food that is lost or thrown away annually will increase to one-third amount by the year of 2030. At that time, "2.1 billion tonnes will either be lost or thrown away, equivalent to 66 tonnes per second".

Keywords: Food loss, Food wastage, Food insecurity, Food waste index, Sustainability

The waste of food is emblematic of a food production and consumption system that cannot be maintained sustainably. According to calculations made by the Boston Consulting Group (BCG), the quantity of food that is lost or thrown away annually will increase to one-third by the year of 2030. At that time, "2.1 billion tonnes will either be lost or thrown away, equivalent to 66 tonnes per second" (Hegnsholt et al 2018). Over 2 billion of population throughout the world does not have regular access to food that is safe in quality terms, nutritious and sufficient enough. This number includes those who suffer from hunger as well as those who are facing moderate levels of food insecurity. Food wastage is an important problem that is directly affecting the environment, the economy, and the society (Dahiya et al 2017, Stenmarck et al 2016). Therefore, to maintain global food security and good balancing environment, food wastage needs to be addressed (Dahiya et al 2017, Stenmarck et al 2016). Food loss (FL) can be defined as "the decrease in quantity or quality of food that makes it unsuitable for human consumption" by the FAO of the United Nations (FAO). Food wastage is a component of food loss and refers to food and its related products that are discarded at the consumer and retailing levels. The possible reason behind that could be an excess purchase, supplying perishable commodity in surplus quantity where it is having a low demand, indeliberate attitude of having leftovers at the household level, and glut in market from surplus level of harvest (Georganas et al 2020, Gustavsson et al 2011).

According to FAO, the food quantity that is lost or wasted in the supply chain is estimated at 1.35 billion tonnes per year that was being produced for consumption needs of human beings but was not consumed. The United Nations (UN) has suggested as an important part of their agenda for sustainable development goals (SDG) with the objective of drastically decreasing global food loss and halving the food quantity that is wasted around the globe by the year 2030 (Commission 2018). India's food grain production has marked a record of 315.70 million tonnes as well as the production of horticulture products was almost 342.30 million tonnes during 2021-22 in spite of all the challenges faced by the economy during this time period (PIB Report 2023). Further, as per the report the production estimates for kharif food grains during 2022-23, was registered at 149.90 million tonnes which was higher than the kharif food grain production during the last five years. Other than the food grains the pulses in the country have also recorded higher than the average of 23.80 million tonnes in the past few years. Apart from all the heights, the issue of food loss and wastages is also equally important. The loss of food occurs at the six main stages viz., at harvesting level, handling and storage level, processing phase, transport and distribution stage, retail and consumption at household level. Quantity of food grains (wheat and rice) that damaged in godowns of FCI during (2016-17 to 2021-22) is mentioned below:

There needs to be a clear distinction between the term food loss and food wastage. Food wastage according to FAO

is considered as “wholesome edible material intended for human consumption, arising at any point in the food supply chain that is instead discarded, lost or degrades” (Gustavsson et al 2011). It is more prominent in higher income countries majorly at restaurants, hotels, homes, etc., whereas, food loss majorly occurs when the food becomes unfit for the human consumption unavoidably even before people have a chance to eat it. Food loss problem can be seen prevalently in lower income countries. (World Food Program USA, 2022). The food grain procurement in the country is done by Food Corporation of India in a scientific manner. But after all the precautions maintained to store the food grains in the godowns, some quantity of food grains may get damaged due to leakage, contamination, natural calamities, etc. The food loss damaged during the last three years is shown in the Table 2.

Food loss is one of the reasons for the cause of hunger nationwide. In the Global Hunger Index of 2022, India's rank was 107th out of 121 countries and having a score of 29.1 that showed a serious level of hunger. Food loss is not only a damage to hunger but a serious issue of threat for our natural resources as it has adverse effects on the environment because that food which is lost had consumed water, soil, nutrients, etc. during its production process and was not even available further for consumption to general public. This causes a dual loss in the form a form of increasing hunger as well as environment issues. In addition to this the world population is also growing, and by the end of 2050, 70 per cent of more food will be needed to feed the future population (Rezaei and Liu 2017). Therefore, to feed the increasing human population and to decrease the damage done to the environment, food loss should be reduced to the minimum level. The reasons behind the food loss and food wastage in the developing country are completely different from that of the developed countries. The main reasons behind the loss and wastage of food in both the type of countries was identified by (Dora et al 2021). The Table 3 given below

Table 1. Quantity of food grains (Wheat and rice) that damaged in godowns of FCI during 2016-17 to 2021-22 in lakh metric tonnes

Year	Quantity handled (offtake)	Damage Accrued in godowns	% of damaged food grains to the total of offtake
2016-17	473.31	0.09	0.02
2017-18	452.16	0.03	0.01
2018-19	500.08	0.05	0.01
2019-20	455.13	0.02	0.00
2020-21	688.57	0.02	0.00
2021-22	766.08	0.02	0.00

Source: India stat (FCI report FAO 2021-22)

shows the major causes of loss in food and wastage in developed as well as developing nations.

According to the UNEP Food Wastage Index Report (2021), the maximum food wastage is done by the lower middle-income groups which is equal to 91 kg/capita/year followed by high income group countries (79 kg/ capita/year). China and India together are producing more household food waste than any other country to the tune of 92 and 69 million metric tons every year, respectively. This fact is not surprising as both countries are having the largest population globally. Food wastage has often been thought to be concentrated in countries with higher income, however, in terms of wastage per capita, there are similarities between developed and developing nations. It is estimated that per capita food waste production is higher in Western Asia and Sub Saharan Africa. The total amount of annual household food wastage produced in selected countries is depicted in the Figure 1.

Food wastage and its impact on food security in India:

According to an estimate 30 to 50 per cent of the food produced in the world is never consumed (Agarwal et al 2013). Food security is a serious issue in the country that is a result of food wastage. According to a project held at Wageninsen University, India is producing adequate amount of food to satisfy every individual but approximately 30-50 per cent food loss is seen in the supply chain and consequently this food becomes unavailable to the general public which results in undernourishment and hunger. Approximately 7 million children in India have died from starvation and malnutrition, and over 194 million people are undernourished. Despite India's high levels of food production, food security is the major problem prevailing in the country. Our country ranked 94th out of 107 nations. The graph shows the trend of Global Hunger Index score from 2000 to 2022.

The graph indicates that the Global Hunger Index Score has increased from 2014 (28.2) to 2022 (29.1). Contrastingly there was increase in the production of food grains from 252.02 million tonnes during 2014-15 to 316.06 million tonnes in 2021-22 (PIB, 2022). But due to food loss the food produced was not available for the general public especially to the lower income group. Therefore, food loss and wastage is considered to be a serious problem that affects our food security. According to a project report given by Wageningen

Table 2. Summary of food loss damage from 2017 to 2020

Year	Quantity of damaged food grains (in MT)
2017-18	2663.49
2018-19	5213.36
2019-20	1930.36

Source: PIB (FCI report FAO 2020)

University and research over 194 million people from India are suffering from undernourishment and almost 7 million children perished from starvation and malnourishment. On the other hand, although the nation produces enough food to feed its people, about 40% of it is wasted or lost. The total value that is estimated for the wastage is around 6 billion euro per year. Apart from food wastage, post-harvest losses in India is also a concerning issue. According to NABCONS study done in the year 2022, the post-harvest losses are as follows; cereals (3.89-5.92 per cent), pulses (5.65-6.74 per cent), oilseeds (2.87-7.51 per cent), fruits (6.02-15.05 per cent), vegetables (4.87-11.61 per cent). According to a report by ICAR-CIPHET the losses are higher in eastern as well as hilly regions (Eastern Maharashtra, Jharkhand, Chhattisgarh and Odisha) and the east coast (Tamil Nadu, Andhra Pradesh, and Odisha coasts) (Jha et al 2015).

Factors responsible for food wastage and loss: Various factors contribute to food loss and waste, depending on the nation's economic circumstances. In developed countries, food loss primarily happens during the consumption stage as a result of food waste in restaurants, hotels, and other establishments; in underdeveloped countries, food loss is a big problem during the production stage. (Calvo-Porrall et al 2017, Godfray et al 2010). Several studies show that age factor is related to the food loss. According to the study of (Secondi et al 2015, Stancu et al 2016) elder people waste less food than young people while some studies showed that food waste increases with age (Cecere et al 2014). Women were held responsible for more food wastage than man in a study done by (Visschers et al 2016), whereas vice versa situation was suggested in the study of (Cecere et al 2014, Secondi et al 2015).

Furthermore, the study done by (Secondi et al 2015) showed that that food loss occurs in case of who are engaged in any kind of employment while some studies showed that there is zero or no correlation among income of a person and food loss (Wenlock et al 1980). Other than these socio demographic factors other factors such as planning habits, knowledge, awareness, personal and subjective norms, etc are also held responsible for the loss of food in the study of (Graham et al 2014, Visschers et al 2016). Food loss and wastage also varies from commodity to commodity (Ahumada and Vilalobos 2009). Poor planning structure of harvesting such as its handling techniques, time of harvesting, inspection, etc. are also majorly responsible for post-harvest losses (Raut and Gardas 2018). The main causes of food loss during the storage stage are inadequate packaging and storage conditions. (Murthy et al 2009, Manikas and Terry 2009). Sometimes during long distances of travel the food and its quality gets deteriorated due to

improper transportation conditions (Cai et al 2008, Rijpkema et al 2014). Behavioural issue is another reason which is also responsible for the loss of food at consumer level (Parfitt et al 2010).

Consequences of Food Loss and Wastage

Environmental loss: Food loss is not also responsible for food security issues but is proven to be a threat for our environment too. It represents the depletion of natural resources needed in the production of food, such as land, water, energy, etc. As a result, it also causes greenhouse gas emissions. (Gustavsson et al 2011). Food loss and wastage is responsible for almost 8 per cent of anthropogenic greenhouse anthropogenic gases (FAO 2013). FAO has also quantified food wastage footprint on natural resources, mostly it is identified as carbon footprint. Statistically, 3.3 billion tonnes of carbon dioxide are produced annually as a result of food waste. Based on FAO estimates, if food waste were a nation, it would rank third globally in terms of emissions.

Carbon footprint intensities: The entire amount of greenhouse gasses released during a food product's lifecycle is measured in kilograms of carbon dioxide equivalents, or its "carbon footprint." Carbon footprint is different for different food products since they have different life cycles. It can be shown in the following diagram. Cereals almost contribute 80 per cent for the carbon footprint followed by the animal products like eggs, meat, milk, etc. As far as fruits and vegetables are concerned carbon footprint created by this group is 6 per cent and the least is created by roots, tubers and pulses of 1 per cent. According to a study done by (Bernstad et al 2015, Saleem et al 2017) food loss and wastage can save greenhouse gases emission ranging from 800 to 4400 kg carbon di oxide equivalent per ton food wastage.

Various approaches for managing food waste: The handling of food wastage can involve a wide variety of practises, including feeding garbage to animals, composting (which produces organic fertilisers), anaerobic digestion, incineration, and landfill disposal. Adhikari et al (2009) observed that illegal open dumps and landfills are the major ways that are involved regularly in the food waste management because of their high use rate for managing the wastage. The most prevalent way for treating food wastage in poor nations is dumping or putting it in landfills, which accounts for more than 90 percent of food wastage treatment, composting is the second most popular method, making for 1–6% of food wastage treatment. Anaerobic digestion is used to treat 0.6% of food waste, while alternative treatments like burning and feeding waste to animals are only very seldom used. Other than these there any many other approaches for food waste management (Fig. 2).

Food wastage used as animal feed: Animals make up 33 percent, 81 percent, and 72 one percent of the total amount of food waste generated, respectively (Gen et al 2006, Kim et al 2011). Laws in Taiwan, South Korea, and Japan all support feeding animals with food wastage. Because separating and collecting of food waste is not adequately practised in poor nations, almost all of the food waste that is generated is mixed with municipal solid waste, which cannot be purified and used for feeding of animals. As a result, almost all of the FW that is generated is wasted.

Anaerobic breakdown of food waste: Since the year 2006, anaerobic digestion (AD) has been widely used for the treatment of food waste in several Asian and European Union nations (Abbasi et al 2012). However, in underdeveloped nations, AD is not yet widely used as a useful therapeutic approach for the management of food waste. According to Christian and Dubendorf (2007), a number of organisations and non-governmental organisations in China and India have established a variety of digestors which are anaerobic in function on a residential and commercial level to enhance AD technique. For example, India has established biogas facilities that are used by numerous institutions and has experimented with AD implementation. In spite of the fact that AD facilities based on food waste have not been built yet at significant level in China, twenty co-fermentation AD projects involving municipal solid waste, farm waste, and manure are either in the planning stages or are already in operation. However, according to Christian and Dubendorf (2007), the majority of these AD is not functioning well as a result of technological problems, inefficient activities, or managerial regulations. Composting and AD are usually used together in Indonesia, the Philippines, and Vietnam for the purpose of waste management in landfills. During this same time period, Jamaica and Thailand have made significant strides towards integrating food waste treatment facilities by utilising AD and the aerobic composting technology, respectively. According to Christian and Dubendorf (2007), the facility in Rayong, Thailand, utilises organic municipal solid waste from the left food, vegetables, and waste from fruit in order to make fertiliser that is organic in nature and bio gas. The Share Biogas Group in the country of Jamaica converts waste wood into biogas using agricultural residues in order to supply electricity to outlying communities.



(UNEP Food waste index report 2021, Statista)

Fig. 1. Total amount of annual household food wastage produced in selected countries

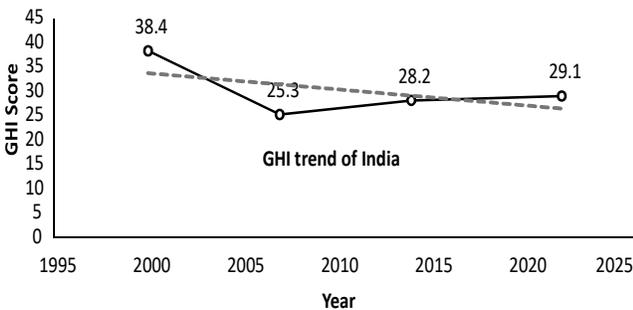


Fig. 2. Graphical representation of GHI score trend for India

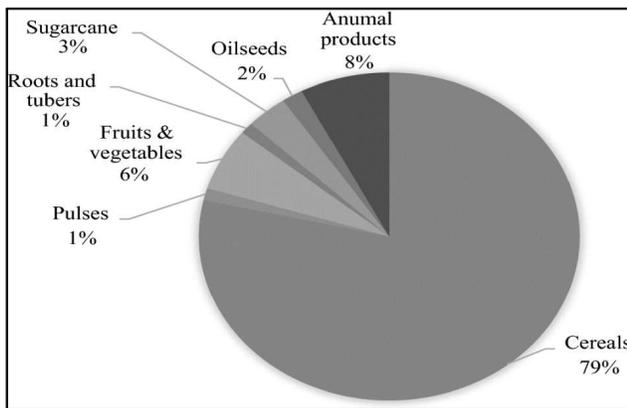


Fig. 3. Contribution of different crops to carbon footprint (Kashyap and Agarwal 2020)

Composting of food waste: In underdeveloped nations, composting is an important and efficient method for reducing the amount of food waste that is produced. More than 70 composting facilities currently operate in India, handling

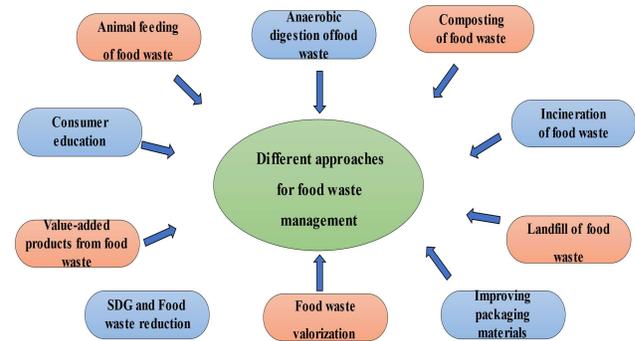


Fig. 4. Different approaches for food waste management

mixed municipal solid waste (MSW). In order to generate more than 4.3 million tonnes of compost annually, these facilities recycle up to 5.9% of the total quantity of food waste. The majority of composting facilities will take mixed garbage, however there are at least two facilities in India, one each in the cities of Vijayawada and Suryapetare, that will take organic waste that has been source-separated (Ranjith et al 2012).

Incineration of food wastage: By burning waste food in an efficient manner, one can cut down on the amount of garbage generated and the size of the landfill that is necessary. This method has been implemented in many countries, including the USA and Singapore (Khoo et al 2010). When compared to other treatment options, incineration is an expensive process because to its high maintenance and heavy capital cost. Furthermore, it demands expensive equipment and highly sophisticated processes in order to cut down on the amount of petrol emissions that are left over. Yates and Gutberlet (2011) recorded the practise of incineration for the treatment of food waste is not widely utilised in developing countries, like Ukraine and Brazil.

Landfill of food waste: Open dumps and landfills are the principal methods for treating FW that are utilised in all developing countries. Open air dumps and landfills accounts for ninety percent of total amount of food waste that is disposed of in landfills. According to USEPA (2020) number of contemporary landfills are able to potentially capture

dangerous emissions from landfills and transform them into the electricity. Adhikari et al (2006) mentioned the percentage of foreign waste that has not yet been separated from municipal solid waste (MSW) is estimated between 20 and 80 percent worldwide. Currently, South Africa, Belarus, China, Jamaica, Ukraine, Nigeria, Vietnam, Brazil, Turkey, Malaysia, Mexico, Costa Rica, Romania, and South Africa are among the nations that dispose of their unsorted foreign garbage in landfills. Other participating nations are Jamaica, South Africa, Belarus, China, and Ukraine. Due to the fact that food waste can break down on its own, landfills are not currently considered a viable alternative for treating food waste (Louis 2004). This is because there is also a risk that food waste in landfills could produce disease vectors. In addition, according to (Adhikari et al 2009), greenhouse gas emissions could rise by 8% as a result of disposing of municipal solid waste in landfills.

Consumer education (awareness): Awareness involves teaching consumers to reduce and recycle food waste. Consumer education needs incremental changes in household food shopping, consumption, and storage habits (Caldeira et al 2019). One of the best ways to reduce food waste is through consumer education, which has an annual potential economic value of \$2.65 billion in the US and a diversion potential of 584,000 tons (Soma et al 2020). Southern Italian case study shows how consumer behaviour affects family food waste. According to the survey age and

Table 3. Major causes of loss in food and wastage in developed as well as developing nations

On farm	Manufacturing	Storage	Distribution and retail or wholesale	Consumption	Hospitality/service industry
Developed countries					
Over production	Lack of training/worse - processing ability	-	Logistic constraint	Consumer preference	Lack of staff capacity
Unharvested products remained on field	Product defects	-	Inaccurate ordering	Strong focus on freshness	Lack of staff
Poor forecasting	Rigorous quantity demand	-	Poor forecasting	Inaccurate planning of purchase	Operational barriers
	Poor Packaging	-	Overstocking	Lack of knowledge to reuse leftovers	Infrastructure
		-	Exceeding expiry date	Behaviour of households	Eating environment
Developing countries					
Poor infrastructure	Use of poor packaging	Poor infrastructure	Pathological loss	-	-
Lack of scientific techniques	Crop loss because of no aesthetic value	Lack of cold storage	Long distance travel	-	-
Poor growing techniques	Crop loss due to inefficient processing techniques	Pest and mold attack	Poor roads facilities	-	-
Low quality equipment for harvesting		Microbial infestation	Inadequate logistic infrastructure	-	-

Source: Dora et al (2021)

education affects food waste. Younger people and the less educated wasted more food (Annunziata et al 2020). Community engagement may be a way to promote food waste reduction and its effects. Participants reduced the food wastage by 50% through Yamakawa, engagement workshops of William community (Yamakawa et al 2017). This shows the power of consumer education. Reducing home food waste can be achieved by extending the shelf life of food, chilling it down and storing it safely, reading labels, finding new uses for leftovers, and sharing excess (Tomson 2018). The World Food Programme estimates that if food waste is minimized, it could feed two billion people annually, 815 million of whom would be able to lead healthy, active lives, and 25% of undernourished individuals in developing nations (World's food waste article 2020). Gamification, such as smart bins (Lim et al 2017, Bandyopadhyay et al 2017), bin cans (Comber et al 2013), and fridge cans are used to monitor and provide food waste feedback. Gamification is the application of game elements outside of games to influence consumer behaviour in online retail through applications (Tobon et al 2020). Consumers will comprehend the impact of food waste on environment and why it should be decreased through environmental campaigns (Lindgren et al 2018). Different rubbish bins are used in industrialised countries. Bin separation shows fundamental understanding of food waste owing to separating the waste at the source. Developing countries lack separation from the sources and municipal garbage pickup.

Improving packaging materials: In order to reduce food waste, items must have better packaging materials to increase their shelf life and improve their quality (Caldeira et al 2019). Retail food waste can be decreased if food products with short shelf lives or those that are about to expire can be made inexpensive and offered at a discount which will encourage customers to buy them off the shelf before they go bad and gets waste. Therefore, if the supply cannot keep up with the demand, food goods that are perishable or have a

short shelf life shouldn't be overstocked. These food items can also be donated to non-profit food bank organisations or charitable trusts that assist the underprivileged, such as the homeless, low-income people who cannot afford to feed their families, and the poor (Lindgren et al 2018).

Food waste valorisation: The adding value to food is the process of valorising food waste. Valorisation refers to turning excess food into goods with increased value or using leftovers or undesired food products-like peels-to make animal feed (Caldeira et al 2019). Food waste generating in huge amounts worldwide along the supply chain has become a valuable resource that can be used as a raw and intermediate material to produce high-value goods. Examples of such products include straw from paddy fields and shrimps used to make packaging materials for food, as well as fuels and chemicals (Cecilia et al 2019, Elhussieny et al 2020). The key component of successfully valuing food waste may be the application of the biorefinery idea. A variety of bio-based goods can be made from food waste. A biorefinery utilising food waste can partially supplement a refinery based on fossil fuels and tackle the main factors driving the bio economy, including resource security, ecosystem services, and climate change (Giroto et al 2015).

Sustainable development goals (SDG) and reduction of food waste: According to Sustainable Development objective 12.3 (FAO(UN) 2020), "By 2030, to half per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses". Minimum food waste reduction initiatives are needed (FAO (UN) 2020). Reduction in food wastage will address second and twelfth sustainable development goals of zero hunger and sustainable production and consumption, respectively (FAO 2020). Many have urged adapting the sustainable development target to reduce the food wastage. World Business Council for Sustainable Development (WBCSD) case study found that DuPont improved the viable shelf life of plant-based European Yoghurt by 10 days, reducing food waste significantly (Thrane 2012). Using a specially engineered bacterium to increase the viable shelf life of plant-based fermented food reduced European yogurt waste by 30% and supply chain waste owing to early expiration (Thrane 2012). A spinach drying case study was published by International Flavours & Fragrances (IFF). The company suggested drying spinach into powder using mild infrared drying to preserve nutrients, colour, and flavour. Hershkowitz (2012) reported that this strategy reduced food wastage and earned 1.3 million USD. This method enables homes to buy powdered spinach for drinks or snack bars, increasing vitamin K intake. Innovative food waste reduction improves

Table 4. Average amount of food wastage for different income groups for different nations (kg/capita/yr)

Income groups	Average food wastage (kg/capita/yr)		
	Household level	Food service level	Retail level
Higher income countries	79	26	13
Upper middle income countries	76	Data not found	
Lower middle income countries	91	Data not found	
Lower income countries		Data not found	

Source: UNEP food wastage index report 2021

nutrition and food security, promotes sustainable development and efficient utilization of natural resources, and lowers production costs, meeting the SDGs 2 & 12.3 goal of zero hunger, per global capital waste at retail and consumer levels, and food losses, respectively, along global production and supply chains by 2030.

Value-added products from food waste: Reduce, reuse, and recycle policies should guide food waste management (Mamma 2020). A sustainable bio economy can develop innovations and value from biowaste, leftovers, and discards. Biofuels from food waste are in keeping with 2015 UN 2030 Agenda for Sustainable Development. More specifically, it relates to the 7th sustainable development goal of affordable and clean Energy, 12th goal of responsible consumption and production and 13th goal of climate action and incentives to help merchants and consumers to minimise food waste to 50% by 2030 (Commission 2018). Reusing food by products and converting food waste is still limited (Mamma, 2020). Food waste and its measurement along the food supply chain, quality and homogeneity data, and national waste legislation implementations are now barriers (Prasoulas et al 2020). Effective and stable food waste biofuel and bioproduct production is gaining attention (Giroto et al 2015). Food waste is now considered as a viable raw material containing carbohydrates (30 to 60%), proteins (5 to 10 %) and lipids (10 to 40 % w/w) (Pleissner et al 2013). After solubilizing food waste, chemical and biological/enzymatic processes can extract carbon, nitrogen, and phosphorus molecules. Various research indicates that food waste can be utilized to create animal feed, which will boost livestock output, as it contains high levels of crude protein, minerals, and other nutritionally valuable bioactive substances.

Hydrolysing of food waste is another method which requires phosphatases, cellulases, Manganin proteases, and glucoamylases. Manganin and Greetham devised a sorghum bran based on biorefining strategy for *Aspergillus awamori*-based glucoamylase synthesis (Manganin et al 2019). The glucoamylase enzyme digested 200 g/L bran of sorghum to create a sugar rich fermentation medium with 38.7 g/L glucose. Sorghum bran hydrolysate can be used as a generic fermentation feedstock for biofuel and biochemical synthesis (El-Imam et al 2019).

Prasoulas and Gentikis (2020) inducted *F. oxysporum* to produce enzymes from wheat straw, bran and maize cob. They hydrolysed food waste using those enzymes to make ethanol. Déniel and Haarlemmer (Déniel et al 2016) showed that hydrothermal liquefaction can produce liquid fuel from food waste, peels and rinds from fruit juice production can be used to make fibres for confectionaries and frozen meals. Fibre increases the fibre content of goods for the elderly,

diabetics, and weight reduction (Badjona et al 2019). In beverage-alcohol fermentation, citrus pulp and molasses are used. Pentose sugars not used by the beverage sector provide great energy for cattle feed (Okonko et al 2009).

By-products of coffee processing include husk and pulp. Its organic content makes it appropriate for value-added products. Soccol Pandey (Pandey et al 2000) suggests using coffee husk and pulp to make fertilisers, livestock feed, and compost. Solid-state fermentation has been used to manufacture enzymes, organic acids, and flavour and fragrance compounds from coffee husk and pulp. Husks and pulp are utilised as organic fertiliser and swine feed (Okonko et al 2009). Farming can also use food waste as organic manure (Lindgren et al 2018). In Nigeria, the dumping of by products from agriculture like trash from cassava crop from processing farms and households also is hazardous to the environment. The conversion of low-value cassava waste into bio sorbent to remove harmful and precious metals from industrial wastewater will reduce environmental pollution and increase market value for millions of cassava producers (Okonko et al 2009). Uzochukwu, Oyede (2011) used cassava garri effluent starch to make 50.1% (v/v) ethanol.

Challenges and Opportunities

At consumer and retail level it is difficult to measure food waste in most cases as it is intermingled and considered non-essential waste (FAO(UN) 2020). The heterogeneous character and high level of moisture in food waste frequently provide challenges for efficient conversion of food waste into valuable products effectively, even with the availability of numerous conventional methods such as landfilling or biogas production (Sindhu et al 2019). A major barrier to effective food waste management is the inability to collect and store food waste in the right ways, as well as to prepare it according to cultural norms and procedures, and to bio convert it into valuable by-products (Lindgren et al 2018, Sindhu et al 2019). Pandemics, natural calamities, and civil upheaval may be responsible for food loss and wastage. The focus switches from the process of gathering and producing or preparing food to just staying alive and safe in such circumstances. Food waste results from a lot of items being neglected and receiving little care, which compromises their integrity and wholesomeness from the farm until they are sold to customers. There are still restrictions to the utilisation of food waste and by-products. There is presently little information available on the generated food quantity in the supply chain, as well as inconsistent national waste regulation implementation and a lack of statistics on the waste's quality and uniformity. As mentioned previously, food waste's composition is unstable. There are notable seasonal, regional, and nutritional differences that are associated with

it. Anaerobic breakdown is one of the important methods of recycling food waste to achieve zero emissions, even with the unavoidable change in the composition of collected garbage (Mamma 2020). High moisture content, a high microbial load, and presence of antinutritional components in plant-based crops and food that may inhibit nutrient absorption are some of the problems that restricts converting the food waste to animal feed (Nikmaram et al 2017). But if adhere to food waste guidelines, can overcome this difficulty. Food waste utilisation has advantages from an environmental perspective as it lowers the methane gas emissions from landfills, preserves the natural resources like coal and fossil fuels, and brings social benefits due to the debate over fuel vs food (Giroto et al 2015). In order to achieve zero emissions, reduce health and environmental problems related to food waste landfills, and reap economic and social benefits, food waste must be effectively used as an intermediate raw material for the manufacturing of value-added finished products. A few technologies for food waste valorisation process have previously been established at the pilot size in the field of hydrothermal liquefaction (Déniel et al 2016). This is still an active research topic. In the process of developing HTL processes, the industry continues to face both technological and financial obstacles.

Future Prospective

The significant problems of food wastage and food loss appear to have a bright future in terms of how they will be addressed. New technologies, such as upcycling processes and management of supply chains powered by artificial intelligence, offer creative answers to the problems of excessive waste and inefficient utilisation of resources. Additionally, the shifting policy landscape is driving food waste legislation, sustainable packaging initiatives, and economic incentive programmes, which together provide a supporting framework for the reduction of waste. Local communities are given the ability to reduce food wastage and redirect the food in surplus quantity to those who are in dire need with the help of initiatives that are led by communities such as networks involved in food recovery and urban agricultural programmes. Even though obstacles still exist, these recent advancements point to a more promising future in which we will be able to construct a system that is more sustainable in nature and robust, hence reducing food wastage and maximising the value of our food resources.

CONCLUSION

It is essential to develop methods of managing food waste that are sustainable because it continues to present a substantial burden to society. Effective and efficient food waste management has positive global effects on the

economy, society, and environment. Redistributing extra food to those in need or social services is a significant step in the process of forming a sustainable system for managing wastage of food. Furthermore, domestic trash, products sold by retailers that is not suitable, and agricultural wastes can all be used as feedstock to make value-added goods like colorants, enzymes, and biofuels. It is possible that educating the general people about how to consume food effectively during a pandemic plays an important role in avoiding future food wastage and ensuring that everyone has access to food. Furthermore, utilizing food waste as a feedstock for producing energy appears to be a viable option. Moreover, the utilisation of biotechnological process used for converting food waste into products with additional value is an essential approach to maximise the utilisation of food wastage, therefore it will decrease the detrimental effects that food waste has on the environment and human health.

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