The Utilization of Food Waste: Challenges and Opportunities

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Abstract

Food waste is a global challenge from collection to disposal. The problem associated with food waste is on the increase ranging from its discharged, lost, degradation and contamination. Food wastage can be effectively managed through proper storage, purchasing what is needed and giving excess to those in need. The most effective means of managing food waste is through effective sorting at source and recycling for industrial processes for the production of value-added products, thereby reducing the options of incineration and landfilling. Research has been carried out on food waste for the production of energy and other value-added products. This review aims to provide a brief overview of food waste from the farm gate, retailer, household and the impact of the pandemic in the increase of food waste. The potential strategies of effectively management of food waste both in developed and developing countries are discussed.

Keywords

Food waste, Value-added products, Disaster, Food waste management

Introduction

Globally, about 1/3 of the food produced is wasted according to the Food and Agriculture Organization (FAO) statistics in 2011 [1]. The problem of food waste (FW) is a global challenge facing humanity worldwide. According to FAO, food loss (FL) is defined as "the decrease in quantity or quality of food that makes it unsuitable for human consumption". Food waste is part of food loss and refers to food products discarded at the retail and consumer levels which could be as a result of an excess purchase, surplus supply of perishable where there is low demand, deliberate/in deliberate attitude to have leftovers at the household levels and market glut from surplus harvest [2, 3]. Food waste also refers to food intended for consumption that is discarded along the food supply chain, which cannot be consumed. Food waste typically consists of 82.5% moisture content, 51.2% carbon, 7.2% hydrogen, 38.1% oxygen, 2.8% nitrogen and 0.7% sulphur [4].

According to the FAO of the United Nations, global food waste is estimated at 1.357 billion tons per year of food produced for human consumption, which is being lost or wasted throughout the supply chain. Part of the sustainable development goals (SDG) agenda by the United Nations (UN), proposed a goal of halving worldwide food waste and substantially reducing global food loss by 2030. Meanwhile, food waste in the European Union is expected to rise from 89 million tons in 2006 to 126 million tons in 2020 where the household sector accounts for 42% of this total figure [5]. Currently, UK households generate 6.5 million tons of food waste per year, of which 4.5 million is edible. Japan,
Table 1: Estimation of food waste in percentage generated in selected
areas around the world.

| Selected Area | Household (%) | Wholesale & Retail (%) | Production & Processing (%) | References |
|---------------|---------------|-------------------------|-----------------------------|------------|
| Africa        | N/A           | 40                      | 40                          | [10]       |
| Australia     | 20            | N/A                     | N/A                         |           |
| Europe        | 53            | 5                       | 30                          | [12]       |
| Canada        | 43            | 7                       | 21                          | [13]       |
| Mexico        | 15            | 16                      | 36                          | [13]       |
| United States | 45            | 7                       | 19                          | [13]       |
| South America | 28            | 39                      | 34                          | [14]       |

China and the Republic of Korea produced 357 million tons of food waste per year, South and Southeast Asia produced 275 million tons annually. In contrast, Sub-Saharan Africa, Latin America, North America and Oceania, North Africa and Western and Central Asia produced around 100 million to 130 million tons of food waste annually [6]. The food waste includes food such as cereal, root and tubers, oilseed and pulse, fruits and vegetables, meat, seafood, milk and egg [7]. In Sub-Saharan Africa, post-harvest losses account for a more significant percentage of food waste [8], which reflects the potential harvested foods leaving the farmers’ field without getting to the consumers. Yearly in Nigeria, 123 million metric tons of food is wasted before getting to the market [9]. The extent of food losses and waste is greater in developed countries where food still suitable for human consumption are being disposed, which is predominantly higher at the retail and consumer levels. However, in developing countries, food loss occurs mainly in the food supply chain at the postharvest and processing levels with less food wastage at the consumer level [9]. Table 1 shows the level of food waste generated at household, retail/food service, production, and processing stage around the world.

Food waste consists of a heterogeneous mixture of carbohydrates (cellulose, hemicellulose, and lignin), proteins, lipids, and inorganic compounds [15, 16], biodegradable waste discharged from all waste management sectors from production to disposal. The management of food waste is a global effort due to its environmental, social and economic impacts [17]. There is a great emphasis on the recovery, recycling, and reconditioning of food waste recently. These efforts are made to convert food waste into value-added products, as shown in figure 1. Currently, the food waste generated is mostly recycled as animal feed and compost, while the remaining quantities are disposed on landfills or incinerated. The inappropriate disposal of food waste may lead to severe health and environmental issues such as greenhouse gas, which significantly contribute to climate change [18]. Food waste also occupies landfill space, contaminates freshwater and increases carbon footprints [19]. In 2019, according to the United Nations Food and Agriculture Organization (UNFAO), about 4.4 billion metric tons of carbon dioxide was produced due to food waste disposal. The carbon dioxide emission is so enormous and has a detrimental effect on human health [20].

The food production system or supply chain requires the combined efforts of actors such as the farmers, industries, retailers and consumers and many factors such as fossil fuels, land, water and human resources are interplayed in this process. During this production process, eutrophication occurs as well as greenhouse gases (GHG) are emitted, which thus, affect the environment. Eutrophication is the process by which the environment becomes enriched with nutrients, increasing the amount of plant and algae growth to coastal waters [21]. Eutrophication from food waste can be generated food waste disposed on landfills, which are washed off to aquatic environment through soil leaching and rain. The first step in reducing food waste generation is by preventing the over-production and over-supply of food. For the food waste generated, studies have been carried out to utilize food waste as raw materials for the production of a broad spectrum of commercially essential products, including: dietary fibre, livestock feed, biogas [22], biopolymers, biobased, biodegradable products (i.e., bioethanol, bio-butanol, biodiesel), enzymes [23, 24], nutraceutical, single-cell proteins, [18], food flavors, bio absorbents [25]. The production of chemicals, materials and energy can be derived from food waste [6] via a sustainable and environmentally friendly process to reduce its effect on the environment [26]. This review focused on the utilization of food waste for the production of value-added products, how effective food waste management could help minimize global food wastage, the impact of pandemic on food wastage, its challenges and opportunities.

Current Practice of Food Waste Generation and Management

Food waste has been connected to issues such as climate change, biodiversity loss, water loss, soil degradation and hunger as well as the loss of nutrient in diets. Food waste can be effectively managed at household levels, retail, production and processing as highlighted below.

Consumer education (awareness)

Awareness entails educating consumers on the importance of food waste reduction and recycling. Consumer education requires a gradual behavioral change and attitude towards household food purchasing, consumption and storage.
pattern [27]. Consumer education was one of the highest-ranked solutions for food waste with an estimated food waste diversion potential of 584,000 tons/year and an economic value of $2.65 billion/year in the United States [28]. A case study from Southern Italy reveals the impact of consumer behavior on household food waste. The result of the survey showed that age and education exposure were factors that influenced food waste. The younger age group and the less educated contributed significantly to food waste within the population [29]. Community engagement has been regarded as a potential avenue for communicating the reduction in food waste practices and its impact. There was a 50% reduction of avoidable food waste by participants through community engagement workshops by Yamakawa, Williams [30], which demonstrates the impact consumer education has in the reduction of food wastage. Food waste at household levels can also be reduced by extending food shelf life and reducing waste through chill out and safe store, learn your labels, getting creative with leftovers, and sharing surplus [9]. According to the World Food Program, if food waste can be curtailed, it would be enough to feed about two billion people each year and about 815 million people to lead a healthy, active life and 25% of people undernourished in developing countries [31]. A technology-based approach (Gamification) has been used such as smart bins [32, 33], bin cams [34], and fridge-cams [35], in monitoring and providing feedback on food waste. Gamification is a game element, design in non-game contexts for behavioral change delivered through technology such as apps by changing the way consumer make decisions in electronic stores [36]. Environmental campaign to consumers on the effect of food waste on the environment will give them a better understanding of its outcome and why it should be reduced [37]. In developed countries, there are separate bins for different waste pick up. In the UK, only about two-thirds of UK households have access to a separate or mixed food waste collection, and these are under threat due to the recent pandemic outbreak (coronavirus) [38]. The bins separation indicates some basic awareness of food waste due to the need for waste separation at the source. These source separation of waste and municipal waste pick up are not available in developing countries.

Improving packaging materials

Improving the packaging materials of products to extend its shelf life and improving product quality is essential to curtail food waste [27]. Food waste can be minimized at the retail level if food products with short shelf life or close to expiry can be sold at a discounted price and made affordable so that consumers could buy it off the shelf before it gets deteriorated and wasted. Subsequently, perishable or food products with short shelf life should not be over-stocked up if the demand would not meet the supply. These food products could be given out to charity organizations or food banks for the vulnerable which includes the homeless, those with low income that cannot afford meals for their families and the poor [37].

Food waste valorization

Valorization of food waste in simple terms is food value addition. Valorization implies the processing of surplus food into value-added products or the utilization of waste or unwanted food product waste, such as peels for animal feed production [27]. The abundant volumes of food waste generated globally throughout the food supply chain have emerged as potential resources, which can be employed as raw material to obtain high added-value products, for example, production of food packaging materials from rice straw and shrimp, fuels and chemicals [39, 40]. The implementation of the biorefinery concept could be an essential part of the successful valorization of food waste. Food waste can be used to produce a spectrum of bio-based products. Food waste biorefinery can complement fossil-based refinery to a certain extent and address the major drivers for bioeconomy such as climate, resource security, and ecosystem services [23].

Sustainable Development Goal (SDG) and Food waste reduction

In line with the Sustainable Development target 12.3 [41], which states that “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”. There is a need to implore strategies that will reduce food waste minimally [41]. Food waste reduction will subsequently solve SDG 2, which is ending hunger and SDG 12, which is ensuring sustainable consumption and production pattern [1]. Adapting the sustainable development goal in reducing food waste has been implored in various ways. DuPont extended the shelf-life of yoghurt by ten days of plant-based foods, and this has reduced food waste drastically according to a case study collated by World Business Council for Sustainable Development (WBCSD) [42]. The company implored the use of a specially formulated bacteria to extend the shelf life of plant-based fermented food and this approach reduced yoghurt waste by about 30% in Europe thus, reducing waste due to early expiry in the supply chain [42]. International Flavors & Fragrances (IFF) reported a case study on the reduction of spinach losses by a drying technology. The company implored the use of gentle infrared drying technology in drying spinach into a powdery form, thus retaining its nutrients, color and taste. This method reduced food losses and waste and has generated about 1.3 million USD additional revenue [43]. This technology has made powdered spinach available on the shelf for households use in a beverage or incorporated in snack bars, thus improving vitamin K intake. Reducing food loss and waste through innovative plays a major role in improving food security and nutrition, promoting sustainable environment and natural resources, and lowering food production costs thus, meeting the SDGs Target 2 & Target 2.3 goal of zero hunger, reducing per global capital waste at the retail and consumer levels and food losses along global production and supply chains by 2030 [44].

The Production of value-added products from food waste

The management of food waste should follow specific policies based on 3R’s concept, i.e., reduce, reuse, and recycle [15]. A sustainable bioeconomy can turn bio-waste, residues and discards into valuable resources and can create innovations.
The exploitation of food waste for the production of biofuels is in line with the 2030 Agenda for Sustainable Development set by the UN in 2015. More precisely, it is directly related to the Sustainable Development Goals: 7. Affordable and Clean Energy, 12. Responsible Consumption and Production, and 13. Climate Action and incentives to help retailers and consumers cut food waste by 50% by 2030 [5]. However, the use of food by-products and the conversion of food waste is still limited [15]. The current limitations in food waste include its quantification along the food supply chain, limited data on its quality and level of homogeneity, and differences in national implementations of the waste legislation [45].

There is an increasing effort currently focusing on the effective and stable means of obtaining biofuel and bio-products from food waste [23]. Food waste with nutrients composition of 30-60% starch, 5-10% proteins and 10-40% (w/w) lipids makes food waste a promising raw material [6]. Chemical and biological/enzymatic methods can be performed for the recovery of nutrients from food waste in the form of carbon, nitrogen and phosphorus compounds after solubilisation of the waste matter [26, 46-48]. Studies have shown that food waste has high crude protein values, minerals, as well as other bioactive compounds of nutritional benefits and this food waste, can also be channelled into animal feed production thus increasing livestock productivity [2, 49, 50].

Most of the food waste matters requires hydrolytic enzymes such as glucoamylases, cellulases, Makanjuola proteases and phosphatases for their hydrolysis [6]. A sorghum bran based biorefining concept was developed by Makanjuola, Greetham [26] for the production of glucoamylase using Aspergillus awamori. The sorghum bran was hydrolyzed using the glucoamylase enzyme produced for the production of a sugar-rich fermentation medium and a glucose concentration of 38.7 g/L from 200 g/L sorghum bran was obtained. They indicate the potential use of sorghum bran hydrolysate as a generic fermentation feedstock for the fermentative production of biofuels and biochemical. Ahmed El-Imam, Greetham [51] exploited sorghum bran a sorghum milling waste for the fermentative production of enzymes using wheat straw, and this food waste, can also be channelled into animal feed production thus increasing livestock productivity [2, 49, 50].

Prasoulos, Gentikis [45] used the induction of F. oxysporum for the production of enzymes using wheat straw, wheat bran and corn cob. They exploited those enzymes for ethanol production through the hydrolysis of food waste. Energy valorization of food processing residues was carried out by Déniel, Haarlemmer [52] showing that liquid fuel can be produced from food waste using hydrothermal liquefaction (HTL).

Food waste obtained from fruits during fruit juice production such as the peels, rinds can be utilized into value-added products such as fibers which can be included in confectionaries and household frozen meals. Incorporation of fibre will improve the fibre content of such products which can be suitable for the elderly, diabetic patients and weight loss [53]. Citrus pulp and molasses serve as a substrate for fermentation in the beverage-alcohol industry. In contrast, the pentose sugars that was not utilized by the beverage industry serve as an excellent source of energy for cattle feed [54].

Coffee husk and pulp are by-products obtained during the processing of coffee. Its richness in organic nature makes it suitable for the production of value-added products. Pandey, Soccol [55], report alternative uses of coffee husk and pulp for the production of fertilizers, livestock feed and compost. Attempts have been made to produce several products from the coffee husk and pulp such as enzymes, organic acids, and flavor and aroma compound through solid-state fermentation [54-56]. Some of the husks are used as organic fertilizer while the pulp also has its utilization in swine feeding [54]. Food waste could equally be compounded into organic manure for farming purposes [37].

The disposal of agricultural by-products such as cassava waste from processing activities from the farm and household is of great concern due to its environmental pollution in Nigeria. Converting these low-value cassava waste into biosorbent for the removal of toxic and valuable metals from industrial wastewater would help prevent its environmental pollution thereby, increasing their market value and thus benefit millions of cassava producers [54]. Uzochukwu, Oyede [57] has reported the effluent starch from garri processed from cassava for the production of 50.1% (v/v) ethanol. Table 2 lists some examples of recent studies on the utilization of food waste for the production of value-added products.

Table 2: Recent studies on the production of value-added products from food waste.

| Substrate used           | Method used                      | Products               | References |
|-------------------------|----------------------------------|------------------------|------------|
| Pea waste               | Dual twin-screw extrusion & microwave hydrothermal treatment | Micro fibrillated cellulose | [58]       |
| Berry pomace            | Extraction                       | Phytochemicals         | [22]       |
| Municipal solid waste   | Transesterification              | Maggot biodiesel       | [59]       |
| Kitchen waste           | Anaerobic digestion              | Biogas                 | [60]       |
| Sorghum bran            | Submerged fermentation           | Glucoamylase enzyme    | [26]       |
| Sweet sorghum           | Fermentation                     | Bioethanol             | [61]       |
| Waste cooking oil       | Valorisation                     | Biodiesel              | [62]       |

Impact of disaster on food waste generation

Depending on the nature and severity of disasters such as flood, earthquake, hurricanes and other risks weaken food security and impact agricultural activities severely [63]. Disaster put food security at risk with food wastages occurring in different disasters where people are displaced from their settlements, death of people, and decrease in agriculture output [63]. Foods are discarded based on their contact with flood or storm water, perishable foods not properly
refrigerated due to power outage and if poorly managed on a large scale, the waste can have significant environmental and public health impacts.

Since, the emergence of the world pandemic coronavirus (Covid-19) the major fear has been food insecurity due to lockdown in several parts of the world. Thus, there is a reduction in food production, processing and distribution [64]. The lockdown has also affected several countries food export and imports trade system. The urban farming system has reduced in several parts of the world as vast swathes of the population are staying home with measures in place to reduce the rate of transmission, to remain safe and virus free [64].

An increase in food waste is expected to rise globally in as much as we are fighting food scarcity due to government instructions to limit trips to the shops for food as far as possible. The restriction has resulted in different household stocking up on food than they need with less need to go out, and this has contributed mainly to excessive food waste during this pandemic. Hence in a bid to have all food products available as at when needed, consumers have the risk to overstock on certain food products and eventually waste these food products. In contrast, some do not even have enough to consume [64].

Creating good habits for the future involves communities supporting one another and households playing their role in cutting down food waste. Individual purchasing what is needed, storing it safely and creatively using up leftovers, thereby helping the planet and supporting the whole community to access food during the challenging time [38] will reduce the amount of food waste generated. Post-harvest waste would be on the increase because of the reduced workforce on the farm to harvest, process and mainly distribute food products across borders due to the pandemic as a result of workers shielding due to underlying health issues, self-isolating and becoming sick themselves. Therefore, food production companies have delay receiving food crops supplies from the farms and on the arrival of some of this produce are unwholesome for processing, and all this contribute to food loss. Equally, the retailers may have logistic issues getting food produce on time from suppliers and on the arrival of this product they cannot withstand a longer shelf life in-store thus contributing to food waste at the retailer's level even before reaching the customers [64]. In Nigeria, 45% of food loss is due to lack of cold storage resulting in a 25% loss of annual income by small farmers [9]. There is a potential in investing in Africa's broken food security value chain as an opportunity to reduce food loss and food waste in all stages of food production.

A survey carried out by Jribi, Ben Ismail [65] during this Covid-19 pandemic in Tunisia showed a behavioral change towards food waste and thus, this reduced food waste in several households. However, the major causes of food waste during this pandemic were overstocking, inadequate food storage and overcooking. Based on the survey carried out baked products had the highest waste records followed by vegetables, then fruits, while fish and meat products had the least waste recorded [65].

**Challenges and opportunities**

It is challenging to quantify food waste from the retail and consumer level because most times, both the edible and the non-essential waste are mixed [41]. Regardless of the existence of various traditional methods of landfills or biogas production used to harness food waste, effective conversion of food to valuable resources is often challenged by its heterogeneous nature and high moisture content [66]. The difficulties in proper collection, storage facilities, cooking methods, cultural lifestyles and bioconversion of food waste to valuable by-products are pointed out as a big hurdle in proper food waste management [37, 66]. Natural disasters, pandemics and civil unrest could contribute to food loss as well as food waste. During such situations, the goal is to be alive and safe, and there is a shift from harvesting and food production or processing. Many products are left unattended to with minimal attention, and this affects the wholesomeness and integrity of such food products right from the farm even before reaching the retailers and consumers, thus amounting to food waste. The use of food by-products and the conversion of food waste are still limited. Food waste is currently limited in its quantification along the food supply chain, limited data on its quality and level of homogeneity, and differences in national implementations of the waste legislation. The composition of food waste, as already said, is not stable. It presents significant variations related to the season, the area, and the dietary habits of the population. Despite the inevitable variation in the composition of collected food waste, recycling through anaerobic digestion is one of the ways in achieving zero-emission from food waste [15]. Food waste conversion to animal feed has some challenges such as high microbial load, high moisture content and the presence of anti-nutritional factors in plant-based food/crops, which could prevent nutrient absorption [67]. However, this challenge can be resolved by following food waste guidelines. The benefits associated with the utilizations of food waste from an environmental point of view include; reduction of methane gas emissions from landfills, preservation of natural resources such as coal and fossil fuels and from the social point of view due to criticism of food versus fuel [23]. The effective use of food waste as a raw material for the production of value-added products is essential for zero-emission, in reducing health and environmental issues associated with food waste landfill, economic and social benefits. The hydrothermal liquefaction remains an active research area with some processes already been developed at the pilot scale for the valorization of food wastes [52]. The industry is still facing technological and economic challenges in the development of HTL processes.

**Conclusion**

The development of sustainable food waste management is essential as it remains a big hurdle for the society. Effective food waste management provides social, economic and environmental benefits globally. Development of a sustainable food waste management could be achieved by redistribution of surplus to the needy or social services. Residues from the
farm gate, households, and retailers not suitable for human consumption can be utilized as feedstock for the production of value-added products such as biofuels, enzymes, colorants. Educating the public on getting what they need at a time during a pandemic will help reduce food waste in the future, thereby making food available for everyone. The opportunity of using food waste as feedstock in energy production seems a feasible option. The use of biotechnology processes in the conversion of food waste to value-added products is a crucial strategy in maximizing the utilizations of food waste, thereby reducing its effect on health and environment through incineration and landfills.

References

1. FAO. 2020. Food loss and food waste. Food and Agriculture Organization of the United Nations: Rome, Italy.
2. Georganas A, Giamouri E, Pappas AC, Papadomichalakis G, Galliou F, et al. 2020. Bioactive compounds in food waste: a review on the transformation of food waste to animal feed. Foods 9(3): 291. https://doi.org/10.3390/foods9030291
3. Gustavsson J, Cederberg C, Sonesson U. Global Food Losses and Food Waste: Extent, Causes and Prevention. Food and Agriculture Organization of the United Nations: Rome, Italy.
4. Shin H S, Youn J H. 2005. Conversion of food waste into hydrogen by thermophilic aerobic/anaerobic Biodegradation 16(1): 33-44. https://doi.org/10.1007/s10531-004-0377-9
5. Commission E. 2018. A sustainable bioeconomy for Europe: Strengthening the connection between economy, society and the environment.
6. Pleisner D, Lin CSK. 2013. Valorisation of food waste in biotechnological processes. Sustain Chem Process 1: 21. https://doi.org/10.1186/2043-7129-1-21
7. Gustavsson J, Cederberg C, Sonesson U. 2011. Global food losses and food waste, in Save Food Congress. The Swedish Institute for Food and Biotechnology: Düsseldorf, Germany.
8. Sheahan M, Barrett CB. 2017. Review: food loss and waste in Sub-Saharan Africa. Food Policy 70: 1-12. https://doi.org/10.1016/j.foodpol.2017.03.012
9. Tomson B. 2018. Food waste in Africa starts long before the grocery store.
10. Cernansky R. 2015. Combating food waste in sub-Saharan Africa.
11. Reynolds CJ, Mavricki V, Davison S, Høj SB, Vlaholias E, et al. 2014. Estimating informal household food waste in developed countries: the case of Australia. Waste Manag Res 32(12): 1254-1258. https://doi.org/10.1177/0734242x14549797
12. Stenmarck, Å., Jensen, C., Quested, T ., and Moateset, G. eds. Characterization and management of food loss and waste in North America. [http://www3.cec.org/islndora/en/item/11774-characterization-and-management-food-waste-in-north-america-foundational-report-en.pdf]. [Accessed on: October 18, 2020]
13. Benitez RO. 2020. Losses and food waste in Latin America and the Caribbean.
14. Mamma D. 2020. Food wastes: feedstock for value-added products. Fermentation. 6(2): 47. https://doi.org/10.3390/fermentation6020047
15. Piritish K, Kuswaha SK, Yadav M, Pareek N, Chawade A, et al. 2017. Food waste to energy: an overview of sustainable approaches for food waste management and nutrient recycling. Biomed Res Int 2017: 2370927. https://doi.org/10.1155/2017/2370927
16. Papargyropoulou E, Lozano R, Steinberger JK, Wright N, Ujang ZB. 2014. The food waste hierarchy as a framework for the management of food surplus and food waste. J Clean Prod 76: 106-115. https://doi.org/10.1016/j.jclepro.2014.04.020
17. Gunjal BB. 2019. Value-added products from food waste. In: Gunjal AB, Waghamode MS, Patil NN, Bhart P. (eds) Global initiatives for waste reduction and cutting food loss. IGI Global, pp 20-30. http://doi.org/10.4018/978-1-5225-7706-5.ch002
18. Buzby JC, Farah-Wells H, Hyman J. 2014. The estimated amount, value, and calories of postharvest food losses at the retail and consumer levels in the United States. SSRN. https://doi.org/10.2139/ssrn.2501659
19. Agency, U.S.E.P., Methane Emissions from Landfills. 2019, Environmental Protection Agency.
20. What is eutrophication? [https://oceana.org/our-work/oceans/eutrophication] Accessed on October 18, 2020.
21. Rohm H, Brennan C, Turner C, Guenther E, Campbell G, et al. 2015. Adding value to fruit processing waste: innovative ways to incorporate fibers from berry pomace in baked and extruded cereal-based foods- a SUSFOOD project. Foods 4(4): 690-697. https://doi.org/10.3390/foods4040690
22. Girotto F, Aliardi L, Cosu R. 2015. Food waste generation and industrial uses: A review. Waste Manag 45: 32-41. https://doi.org/10.1016/j.wasman.2015.06.008
23. Lam WC, Pleisnser D, Lin CSK. 2013. Production of fungal glucoamylase for glucose production from food waste. Biomolecules 3(3): 651-661. https://doi.org/10.3390/biom3030651
24. Laufenberg G, Kunz B, Nystroem M. 2003. Transformation of vegetable waste into value added products: (A) the upgrading concept; (B) practical implementations. Bioresource Technol 87(2): 167-198. https://doi.org/10.1016/j.biortech.2001.05.034
25. Makanjula O, Greetham D, Zoa X, Du C. 2019. The development of a sorghum bran-based bioefltering process to convert sorghum bran into value added products. Foods 8(9): 279. https://doi.org/10.3390/foods8090279
26. Calderiza C, De Laurentius V, Sala S. 2019. Assessment of food waste prevention actions: development of an evaluation framework to assess the performance of food waste prevention actions. JRC Technical Reports, European Commission.
27. Soma T, Li B, Maclaren V. 2020. Food waste reduction: a test of three consumer awareness interventions. Sustainability 12(3): 907. https://doi.org/10.3390/su12030907
28. Annunziata A, Agovino M, Ferraro A, Mariani A. 2020. Household food waste: a case study in Southern Italy. Sustainability 12(4): 1495. https://doi.org/10.3390/su12041495
29. Yamakawa H, Williams I, Shaw P, Watanabe K. 2017. Food waste prevention: lessons from the Love Food Hate Waste campaign in the UK. 16th International waste management and landfill symposium, S. Margherita di Pula, Sardinia, Italy, pp 2-6.20
30. World’s food waste could feed 2 billion people. [https://www.worldvision.org/hunger-news-stories/food-waste] Accessed on Oct 18, 2020.
31. Lim V, Funk M, Marcanaro L, Regazzoni C, Rauterberg M. 2017. Designing for action: an evaluation of social recipes in reducing food waste. Int J Hum Comput Interact 32(3): 187-202. https://doi.org/10.1080/10447318.2016.12.005
32. Bandypadhyay J, Dalvi G. 2017. Can interactive installations bring about behaviour change? Using interactive installation to change food waste behaviours. International Conference on Research into Design 2: 235-245. https://doi.org/10.1007/978-981-10-3521-0_20
33. Comber R, Thieme A. 2013. Designing beyond habit: opening space for improved recycling and food waste behaviors through processes of persuasion, social influence and aversive affect. Pers Ubiquitous Comput 17(6): 1197-1210. https://doi.org/10.1007/s00779-012-0587-1
34. Ganglbauer E, Fitzpatrick G, Comber R. 2013. Negotiating food waste:
using a practice lens to inform design. *ACM Trans Comput Interact* 20(2): 1-25. https://doi.org/10.1145/2463579.2463582

36. Tobon S, Ruiz-Alba JL, Garcia-Madariaga J. 2020. Gamification and online consumer decisions: Is the game over? *Decis Support Syst* 128: 113167. https://doi.org/10.1016/j.dss.2019.113167

37. Lindgren E, Harris F, Dangour AD, Gasparatos A, Hiramatsu M. 2018. Sustainable food systems - a health perspective. *Sustain Sci* 13(6): 1505-1517. https://doi.org/10.1007/s11625-018-0586-x

38. Rutherford O. 2020. Four ways to reduce food waste during coronavirus lockdown.

39. Cecilia JA, García-Sancho C, Maireles-Torres P, Loque R. 2019. Gamification and nutrient composition of different sources of food waste and their potential for use in sustainable swine feeding programs. *Decis Support Syst* 135: 107288. https://doi.org/10.1016/j.dss.2020.107288

40. Yan S, Yao J, Yao L, Zhi Z, Chen X, et al. 2012. Fed batch enzymatic hydrolysates and eventually the ethanol fermentation by *Saccharomyces cerevisiae* HO58. *Braz Arch Biol Technol* 55(2): 183-192. https://doi.org/10.1590/s1516-89132012000200002

41. Prasoulos G, Gentikis A, Konti A, Kalantzis S, Kekos D. et al. 2020. Bioethanol production from food waste applying the multiphase system produced on-site by *fusarium oxysporum* f3 and mixed microbial cultures. *Fermentation* 6(2): 39. https://doi.org/10.3390/fermentation6020039

42. Gustafson S. 2019. New insights into food loss and waste. [https://www.ifpri.org/blog/foa-sofa-report-2019-new-insights-food-loss-and-waste] Accessed on: October 18, 2020.

43. Thrane M. 2012. Tackling food loss and waste: supporting plant- and nutrient composition of broiler chicks. *Asian Australas J Anim Sci* 15(1): 87-92.

44. Food and Agriculture Organization of the United Nations. [http://www.fao.org/3/CA2640EN/ca2640en.pdf] Accessed on: October 18, 2020.

45. Donaldson S, Mezitis S, Hall-Jones T, Duthie G, Williams P, et al. 2009. Defibrillated celluloses via dual twin-screw extrusion and microwave hydrothermal treatment of spent pea biomass. *ACS Sustain Chem Eng* 7(13): 11861-11871. https://doi.org/10.1021/acssuschemeng.9b02440

46. Kim JH, Lee JC, Pak D. 2011. Feasibility of producing ethanol from food waste. *Waste Manag* 31(9-10): 2121-2125. https://doi.org/10.1016/j.wasman.2016.10.054

47. Okonko IO, Adeola T, Atanda O. 2011. Utilization of food wastes for sustainable development. *Elec J Environ Agricult Food Chem* 8(4): 263-286.

48. Rutherford O. 2020. Four ways to reduce food waste during coronavirus lockdown.

49. Prasoulos G, Gentikis A, Konti A, Kalantzis S, Kekos D. et al. 2020. Valorisation of shrimp and rice straw waste into food packaging applications. *Ain Shams Engineering Journal* In press.

50. Khajeh-Nassab M, Shamsi-Jazi S. 2012. Tackling food loss and waste: supporting plant-based foods by extending the shelf life of yogurts by ten days. *DuPont Nutrition & Biosciences* Geneve, Switzerland.

51. Hershkowitz M. 2012. Drying technology turns otherwise-lost spinach into viable new products. *IFF*. Geneve, Switzerland.

52. Déniel M, Haarlemmer G, Roubaud A, Weiss-Hortala E, Fages J. 2016. Energy valorisation of food processing residues and model compounds by hydrothermal liquefaction. *Renew Sust Energ Rev* 54: 1632-1652. https://doi.org/10.1016/j.rser.2015.10.017

53. Badjona A, Adufo, J, Amoah I, Diako C. 2019. Valorisation of carrot and pineapple pomaces for rock buns development. *Scientific African* 6: e00160. https://doi.org/10.1016/j.sciaf.2019.e00160

54. Uzochukwu SVA, Oyedee R, Atanda O. 2011. Utilization of Gari industry effluent in the preparation of a gin. *Nigerian Journal of Microbiology* 15(1): 87-92.

55. Pandey A, Socol CR, Nigam P, Brand D, Mohan R, et al. 2000. Biotechnological potential of coffee pulp and coffee husk for bioprocesses. *Biochem Eng J* 6(2): 153-162. https://doi.org/10.1016/s1369-703x(00)00084-x

56. Kumar SS, Swapna TS, Sabu A. 2018. Coffee husk: a potential agro-industrial residue for bioprocess. In: Singhania R, Agarwal R, Kumar R, Sukumaran R (eds) Waste to wealth. Energy, Environment, and Sustainability. Springer, Singapore, pp 97-109. https://doi.org/10.1007/978-981-10-7431-8_6

57. Nahar K. 2011. Sweet sorghum: an alternative feedstock for bioethanol. *Intern Energy J & Environ* 2(1): 58-61. https://doi.org/10.3390/energyj20100058

58. Gao Y, Xia H, Suleman AP, de Melo EM, Dugnose TJJ, et al. 2019. Defibrillated celluloses via dual twin-screw extrusion and microwave hydrothermal treatment of spent pea biomass. *ACS Sustain Chem Eng* 7(13): 11861-11871. https://doi.org/10.1021/acssuschemeng.9b02440

59. Liu Y, Zheng D, Yao B, Cai Z, Zhao Z, et al. 2017. A novel bioconversion process for value-added products from food waste using *Musca domestica*. *Waste Manag* 61: 455-460. https://doi.org/10.1016/j.wasman.2016.10.054

60. Niu Y, Zheng D, Yao B, Cai Z, Zhao Z, et al. 2017. A novel bioconversion process for value-added products from food waste using *Musca domestica*. *Waste Manag* 61: 455-460. https://doi.org/10.1016/j.wasman.2016.10.054

61. Woon KS, Lo IMC. 2016. A proposed framework of food waste collection and recycling for renewable biogas fuel production in Hong Kong. *Waste Manag* 47: 3-10. https://doi.org/10.1016/j.wasman.2015.03.022

62. Alhammadi AA, Ali Alhousani SM, Saif Hasan Alhammadi FM. 2019. Valorization of waste cooking oil. *ASET*. 79: 62-73. https://doi.org/10.1016/j.aset.2019.08.001

63. Birgitte Wells, Sarah Smooker, Niki Maak, et al. 2019. Food waste treatment technologies for food security: Probing Southern African Development Community channels for influencing national policy. *Jàmba* 10(1): 468.

64. Food Agriculture Organization of the United Nations. [http://www.fao.org/policy-support-tools-and-publications/resources-details/en/c/1276396/] Accessed on: October 18, 2020.

65. Sihui S, Ismail HB, Doggu D, Debbabi H. 2020. COVID-19 virus outbreak lockdown: What impacts on household food waste? *Environ Dev Sustain* 22: 3939-3955. https://doi.org/10.1007/s10668-020-00740-y

66. Sindhu R, Gnansounou E, Rebelo S, Binod P, Varjani S, et al. 2019. Conversion of food and kitchen waste to value-added products. *J Environ Manag* 241: 619-630. https://doi.org/10.1016/j.jenvman.2019.02.053

67. Nijmegen M, Leong SY, Koubaa M, Zhu Z, Barba FJ, et al. 2017. Effect of extrusion on the anti-nutritional factors of food products: an overview. *Food Control* 79: 62-73. https://doi.org/10.1016/j.foodcont.2017.03.027

68. Badjona A, Adufo, J, Amoah I, Diako C. 2019. Valorisation of carrot and pineapple pomaces for rock buns development. *Scientific African* 6: e00160. https://doi.org/10.1016/j.sciaf.2019.e00160

69. Uzochukwu SVA, Oyedee R, Atanda O. 2011. Utilization of Gari industry effluent in the preparation of a gin. *Nigerian Journal of Microbiology* 15(1): 87-92.