The environmental hazards of food wastage: A brief summary

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The increasing volume of wastage of food has become a global problem. According to a recent report of Food and Agriculture Organization of the United Nations, food waste causes economic and ecological deterioration. This chapter would discuss the different food supply chains and occurrences of food wastage. The appropriate indicators for environmental deterioration of food waste, namely acidification, eutrophication, global warming, human and eco-toxicity and depletion of resources, would be discussed. The chapter would also focus on the potential measures for the prevention of food wastage. It would then conclude the critical factors at the end.

Keywords: Food wastage; environmental impact; indicators

1. Introduction

Food wastage refers to the reduction in the availability of food for consumption occurring throughout the food chain, both due to lack of efficiency (poor infrastructure, poor technology and poor management) and due to unintentional discarding of edible items at the retailer's and consumer's end [1]. Globally, food waste is being generated in enormous amount and has become a major cause of concern because of its impact on the environment. About 50 % of the food is wasted globally through the food supply chain [2]. The food waste has not been measured or managed in a regular manner. As for instance, food and organic wastes are often considered together, whereby it becomes difficult to figure out or measure the food-only portion, while in other cases, the reporting is considered for mixed solid waste, only at the stage of disposal [3].

1.1 Food crises

The price of food has been low till the early 2000s, and therefore, the governments of both developing and underdeveloped countries did not invest much in the local agricultural production. However, the reliability on food imports, for food security, suffered a setback when the international food prices started soaring since 2006. As an immediate reaction, such surge in food prices leads to widespread riots and protests in many countries which threatened the stability of the respective governments [4]. According to the report of World Bank, in 2011, about 44 million people were pushed into poverty, as the food prices reached the unaffordable limit [5]. Such situation where a substantial population is forced to starve for food is generally referred to as the "food crisis". It is estimated that about 925 million people are subjected to chronic hunger, throughout the world [6]. However, besides food production, a sustainable food system may also depend on factors including food consumption and food wastage.

1.2 Food supply chains

The food supply chain is a combination of various stages (interlinked to each other) through which food reaches the consumer. These stages may be broadly categorized into two groups, namely inbound logistics and outbound logistics. The inbound logistics may include facilities such as suppliers (delivery of raw materials), factories (manufacturing and packaging), while the outbound logistics may include transportation to storage facilities that is accessible to the consumers (distribution centers and retail outlets). Again, the supply chains, for different products, may intersect at one or more stages. [7].

This chapter would therefore discus in length the occurrences, indicators and prevention of food wastage.

2. Occurrence of food wastage

According to the report of Food and Agricultural Organization of the United Nations (FAO), about one-third of the food produced worldwide, amounting to 1.3 billion tons (per year), is wasted [8].

The wastage of food may take place through spillage, breakage and degradation (especially, during handling and transportation). The environmental impact becomes more severe/or intense with the passing stages (along the food supply chain), as the impacts (or cost) is added to the initial production impact. The wastage may occur at any part of a supply chain: production (at agricultural production), manufacturing and processing, wholesaling and retailing, as well as at the consumer's end. The loss of raw, intermediate or final products may also occur during international and/or domestic trading. The different parts of the food supply chains, of vegetable and animal commodities, where the probable food waste occurs may be depicted as follows [9]:

2.1 Production stage

During harvesting of the agricultural products, their accidental or unavoidable damage and/or spillage may occur. Again, during the handling, storage and transportation of the harvested crops, a portion may get spilled or damaged (through degradation). During breeding, animals and/or birds may die due to sickness and/or accidents. Again, during fishing there is always a discarded portion, while at dairy production units, the cows may get sick whereby its production of milk get reduced. Animals may die during transportation and fishes are lost during icing, packaging, storage and transportation. The produced milk may get spilled or degraded on its way to the subsequent unit.

2.2 Manufacturing and processing

Besides the losses due to spillage (or degradation) at the manufacturing units, a significant portion may also get lost at preparation units, such as washing, slicing etc., prior to their introduction to the former. At the industrial processing unit, meats are lost due to trimming spillage and fishes are lost during canning and smoking. Again, during the treatment of milk, such as pasteurization or processing of cheese/yoghurt, a substantial portion gets spilled.

2.3 Wholesaling and retailing

Losses may take place during handling, shifting, storage and transportation at the market system.

2.4 At consumer end

The wastage of food at the domestic level, namely handling, preparation and consumption.

3. Indicators for environmental deterioration by food wastage

LCA is a process of evaluating the effects that a product has on the environment over the entire period of its life.The LCA study starts with the identification of objectives. The product system is then examined in terms the impact categories namely acidification, eutrophication, global warming, eco-toxicity (in relation to human) and depletion of resources. The technique of Life Cycle Assessment (LCA) is one of the effective tools for studying the environmental impacts, as it considers all the stages of a food supply chain. This tool facilitates the investigation and evaluation of the effects (on air, water and land) of stages (of food supply chain), namely agricultural production, material and component preparation, distribution, consumption and end-of-life management (such as disposal, recycling etc). Certain preselected reference substances have been used to express the results of LCA, like CO_2 for climate change impact, SO_2 for acidification and ethene (C_2H_4) for Photochemical Ozone creation potential etc [10].

3.1 Acidification and Eutrophication

Acidification refers to the emission of gasses, such as SO_2, NOx, HCl and NH_3, into the air, which subsequently interact with the atmosphere to acidify the ecosystems. *Eutrophication* is the excessive growth of plants, namely algae, periphytons and weeds, within water bodies (such as lakes, streams and estuaries), caused by the excessive nutrients content produced as a result of the presence of gasses, namely NOx, NH_3, PO_4^-, in water and air. The sources of such nutrients may include fertilizers (from agricultural fields), soil erosion, discharge from sewage treatment plants, atmospheric nitrogen and run-off from lawns/fields. Eutrophication may cause the reduction of oxygen, during the decomposition of dead plants, which would be fatal for other organisms. Pollution of water resources with pesticides and fertilizers may stimulate the excessive growth of aquatic plants and algae, which would result in clogged waterways, depletion of dissolved oxygen and blocks sunlight from reaching deeper. It has detrimental effect on the process of respiration of aquatic life [11].

Nitrate is leached from all types of soils and gets carried away by the drainage water. The sewage treatment plants also discharges substantial amount of nitrate. These sources of nitrate contribute to the eutrophication of water bodies, mainly, coastal waters, marine waters and lakes. [12]. The soil, in the agricultural land, is contaminated with nitrate during the decomposition of organic matter (including manures). This nitrate is transported to the drainage water during rainfall. Again, excess of phosphorus gets deposited into the soil (of farmland) due to the practice of adding inorganic phosphate fertilizers. The excreta of the animals (including human sewage), which are fed with the crops grown on phosphate contaminated soil, also contain phosphorus. Thus, the phosphorus gets carried away into the waterways. Ammonia is released into the soil through livestock wastes (particularly from cattle, poultry and pigs). The release of ammonia into the air leads to the formation of ammonium particles, which causes smog formation as well as acidification. [12].

3.2 Global warming

Global warming indicates the trapping of a portion of the reflected outgoing solar energy, whereby retaining heat into the lower atmosphere in the vicinity of the earth's surface. Such phenomenon is caused by the emissions of greenhouse gasses (namely, CH_4, N_2O and CO_2) into the atmosphere.

The soil releases CO_2 through its respiring plant roots as well as decomposed organic matter (caused by soil microbes). The N_2O gas is released from the soil due to the processes of nitrification and denitrification (carried out by microorganisms), which are initiated in the presence of nitrogen (in the soil). The soil is being continuously fed with nitrogenous compounds in the form of fertilizers, feces, slurries, manure etc. The CH_4 gas is being released from anaerobic soils and animal wastes. Food wastage of cereals produces 34 percent of the total greenhouse gases [13]. The main causes are the application of nitrogenous fertilizers (during production) and usage of diesel (during agricultural operations, namely ploughing, harvesting and drying). Such usage of nitrogenous fertilizers reduces during the production of pulses as the latter, being a leguminous plant, has the ability to fix nitrogen from air. Similarly, the requirement for nitrogenous fertilizers and diesel is less for the production of potatoes and other roots, thanks to their efficient and high yield. However, the production of grains requires higher usage of nitrogenous fertilizers and diesel as compared to fruits production. The monogastric animals, such as pigs and poultry, contribute to N_2O emissions through their feeder, while CO_2 emissions occur during the production of mineral fertilizers. The usage of energy during maintenance of the animal's shelters also adds to the overall emissions due to certain animals (like chicken). The ruminants, including cattle, sheep and goats, contribute to the emissions of CH_4 gases, especially during feed digestion (due to enteric fermentation) and manure management. Additionally, N_2O emissions also occur during the production of fertilizers, soil emissions and energy usage (in arable farming). In fisheries, the consumption of diesel (during on-board fishing) and leakage of refrigerants (from on-board cooling equipment) adds to the CO_2 emissions. In aquaculture, the emission of greenhouse gases occur during the production of fishmeal and fish oil (in industrial scale) [14].

3.3 Human and eco-toxicity

Human and eco-toxicity refers to the exposure to pesticides and heavy metals which cause harm to human and the ecosystem (consisting the flora and fauna). The rising occurrence of pest and disease has prompted the use of enormous amount of hazardous pesticides [15]. Generally, herbicides are less hazardous to human health than insecticides [16]. In agriculture, environmental hazards include the emissions of gases (such as ammonia), pollution of surface and groundwater due to nitrate and/or phosphate leaching, erosion of soil and harmful effect on biodiversity [17,18].The excessive use of fertilizers and pesticides, in modern agriculture, has negative impact on the natural habitats as well as genetic diversity. As for instance, a sensitive plant like tobacco needs multiple applications of pesticides, fungicides and herbicides during its growing season [19]. Every year 27 million pounds of pesticides are sprayed onto tobacco fields in the United States [20]. Besides causing harm to birds and small animals, it causes "green tobacco sickness", which affects the field workers who are constantly exposed to these pesticides [21]. Besides carbon dioxide, enormous amount of solid waste and/or chemical waste (including paper, ink, foil, glue and cellophane) are generated in the production of cigarettes [22]. Moreover, tobacco smoke is known to contain toxic substances (including carcinogens) [23]. About 0.1% of the applied pesticides reach its target, while the remaining is released into the environment and thus contaminates soils, plants, air and water bodies. The effects of pesticides on living species lead to tropic effects on biodiversity. The application of sewage sludge on land introduces a wide range of toxic heavy metals and organic compounds which subsequently gets assimilated by plants and animals [12].

3.4 Uses of resources

Use of resources indicates the depletion of resources (especially non-renewable), namely fuels, water and agricultural land, due to extraction and consumption. An instance of the depletion of resources includes the use of cropland and/or grassland for the production of that portion of the total foodstuffs which is ultimately wasted. Similarly, during the energy-intensive processing of food, solid waste and wastewater is generated. During the preparation of food at home, substantial amount of energy is used for freezers, refrigerators and cooking and thus has a negative environmental impact.

Land may be used for agriculture, buildings or roads , which may result in deforestation, urbanization and soil sealing. Again, aquaculture may be interconnected to land-use by virtue of the agricultural products used as feed for fish. During livestock production, lands are occupied for the production of animal feed including grazing. As for instance, ruminants are fed with roughages and/or grains and soy-meal as well as other supplements. Again, monogastric animals may also be connected to non-arable land as their feed may contain components of milk from ruminants that require grassland. Among food crops, cereals contribute about 4-15 % of the total arable land occupation of food wastage. However, starchy roots, vegetables and legumes compensate for their food wastage volumes with high yields. At the agricultural production stage, 99% and 50% of food wastages occur in the regions with moderately (and/or highly) and lowly degraded soil, respectively.

The biodiversity comprises of life on earth including diverse genes, species and ecosystem. The greatest harm to tropical biodiversity may be caused by the extension of crop production. The industrial and urban expansions,

especially in the developed countries, have caused the loss of habitat, pollution of the ecosystem and the reduction in the farmland diversity. Moreover, the growing abandonment of agricultural land has led to the decline in the habitat heterogeneity, whereby causing a further decline in biodiversity. In animal husbandry, large stretch of natural areas are converted to pastures as well as used for forage production, which in turn has enormous impact on the biodiversity. Additionally, decline in the genetic diversity of livestock also affects the biodiversity. Biodiversity is also influenced by the alteration of the marine ecosystem prompted by the increasing fish and/or seafood production. The modern industrial fishing destroys sea-floor habitats. Moreover, the discarded alien/unwanted species (as waste), the continuous introduction of hormones and/or antibiotics, the genetic mutation (of wild fish) and the transmission of diseases have narrowed the diversity of the biosphere.

Land with thin topsoil layer suffers from soil loss due to conventional tillage and heavy rainfall [12]. About 60% of used water resources goes to agriculture [24]. In horticulture, the practices of using glasshouses, poly-tunnels and mulches (and/or fleeces) affect the landscape [25]. The depletion of water resources (suitable for use) is caused by its pollution through the improper use of pesticides and fertilizers.

4. Measures for prevention of food wastage

Ecological agriculture (or agro-ecology) involves intercropping, recycling of manure and food scraps into fertilizers, agro-forestry (to maximize resource efficiency) and many other agronomic techniques. Variation in farming systems leads to diverse diets and thus improves the nutritional level. It reduces the expenses (for farming) and thus contributes to better livelihoods. Shifting the mode of agriculture from industrial to ecological could be easily done (both national and international) with the cooperation of the respective government agencies [26]. Introduction of food info-Marts (market for ecological product) is an efficient and effective tool through which the flow of information (and resources) could be mutually shared and/or exchanged.

The development of Ecological Debt Index which would take into account the overall carbon emissions, water consumption, application of chemical fertilizers and/or pesticides on agricultural land etc, would indicate the ecological impact of the product (throughout the food supply chain). A food label, indicating the ecological debt index, would be introduced for all product so that the consumers can make their choice/or preference for product received through greener supply chains.

Reduction of food wastage may be accomplished by improving poor (or inappropriate) practices along the different stages (of food supply chain), namely agricultural, processing, transportation and distribution . Methods like by-product recycling, anaerobic digestion, composting and incineration are advantageous (and beneficial) over mere dumping in landfills [27].

Fertilizers contribute to the emission of green house gases by virtue of the inefficient manufacturing technologies, use of coal (as energy source), preference of urea fertilizers over ammonium nitrate, and its over-application (especially in horticulture) [28, 29]. Improved fertilizer management, conservation tillage, use of biogas as well as farming of productive livestock breeds by using feed additives and antibiotics are some important adoptive measures to reduce emissions. In organic farming, diversified crop rotation is practiced and the use of pesticides, herbicides or inorganic fertilizers is avoided. It enhances biodiversity (in agricultural landscapes), increases species richness by 30% [30]. The practice of high yielding crop production with efficient nitrogen use may diminish the need for synthetic fertilizers, expansion of agricultural land and change of forests (habitats) of technologies, namely slurry injection, manure treatment and well-timed manure application, serve the purpose of maintaining ammonia reductions, nitrogen conservation and reduced fertilizer application. The adoption of anaerobic digestion method promises to improve nitrogen efficiency by replacing synthetic fertilizers with the nitrogenous by-product of anaerobic digestion. The practice of intensified agriculture on suitable productive soils may encourage the slowing and reversing of deforestation [31]. Use of buffer strips and spatial planning for livestock production reduces emissions of green house gases [32].

The practice of sustainable agriculture refers to the use of resources without compromising with the environmental quality and quantity of natural resources. Agricultural sustainability demands optimal utilization of water, crops, soil fertility and soil physical properties. Such practice minimizes chemical and energy inputs and helps improve soil fertility and crop production through synergic ecological interactions [11].

5. Conclusion

Although biodiversity and the effects of varying agricultural practices on landscape do not fall within the domain of LCA methods, however, it covers several important factors, including greenhouse gas emissions (affecting climate), acidifications (acid gas emissions), eutrophication (nitrifying emissions), ozone depleting substances and depletion of resources (both biotic and abiotic). LCA takes into consideration the impacts on all media of the environment, namely land, air and water [10].

Deforestation causes an increase in the atmospheric level of carbon dioxide, severe flooding, soil degradation and restricts water recycling (of nature), which ultimately leads to the extinction of plant and animal species [33,34]. The

treatment of waste, generated by livestock farms, is normally inappropriate, as reported in the state of the environment report 2002 [35]. Livestock waste contributes substantially to the release of COD (chemical oxygen demand), Nitrogen, Phosphorus and heavy metals [36]. The released nitrogen enters the atmosphere in the form of N_2O and/or NH_3, accumulates into soils and contaminates water bodies. The food supply chain may affect the nutritional quality of food. As for instance, fresh vegetables undergo deterioration during transportation, handling and storage [25]. Adoption of preservation methods, namely refrigeration, chlorination, electrolyzed water treatment, ionization (through radiation), packaging and surface coating, may increase the shelf-life of fresh vegetables as well as reduce nutritional loss and physical damage [37].

Water is inseparable in every aspects of life and hence special attention should be given to the development, utilization and protection of water in both the developed and developing countries. The inappropriate use of water for irrigation may cause water depletion, salinization, water –logging or soil degradation.

Adoption of strategies (in sustainable agriculture), namely tillage, crop rotations and use of plant residues as manure, affects soil habitats and the food web and also changes the quality of the soil. The soil biota is involved in the process of decomposition (of organic matter) and maintains the nutrient and carbon cycles. Plants play a crucial role in maintaining the porosity and organic matter content of the soil. Plants are also involved in the bioremediation of toxic wastes [38].

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