An Overview of Food Waste and Its Conversion Technology Into Animal Feeds

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Abstract

Food waste has been a global concern for the human population for a long time and it has hampered food security and environmental sustainability a lot. Food waste is any food or its unconsumable part that is discarded from the supply chain. Existing literature highlighted well the viability of using food waste in animal feeds and the safety and logistical issues that may arise. With the advancements in recent food technology and research, it's now possible to convert food waste into valuable products that work as feed for animals. Generally, three different technologies wet based, dry based and fermentation-based are in use for the conversion of food waste into animal feed without compromising its nutritional values. Different value-added products have directly been extracted from food wastes using these technologies, from flavonoids to essential oils, and reused in various foods such as fruit juices as a flavouring agent. Amongst them, cheese whey is the most researched by-product and serves as an appropriate example of waste valorization. This review extensively emphasizes different food wastes based on their sources and the use of the latest technologies for their conversion to animal feed. The study also suggests different measures for reducing food waste while maintaining animal development and health along with environmental sustainability.

1. Introduction

Food goes from its origin (Farm) to an end customer through food supply chains, including production, harvesting, processing, handling, distribution, and retailing. During all these steps many technical, economical, and sociological factors come into play resulting in food wastage. Experts in the food industry have different opinions on the understanding of "food loss" and "food waste." According to the Food and Agriculture Organization (FAO), food loss refers to the nutritious elements of a plant or animal product that is eventually not consumed by humans, to definitions published (Conrad and Blackstone, 2021).

According to the United Nations Environment Program (UNEP), the food that has accomplished the food supply network up to a final product that is of high quality and fit for feeding but is not eaten due to waste, regardless of whether it has gone bad or expired is termed as food waste. Food waste happens at the trade and feeding stages of the food chain, most commonly (but not always) (UNEP, 2022).

Food waste is among the most complicated problems that humanity is now confronting. Food systems are currently ineffective; one-third to half of all produced food is expected to be wasted before reaching a human (Elliot et al., 2017). More than 1.3 billion tons of edible food materials are wasted worldwide every year, including fruits and vegetables accounting for over 45–50% of the loss and are enough to feed more than one billion people (Georganas et al., 2020; Zutshi, 2018). Food waste happens throughout the food chain, from field to fork (Xue et al., 2017). Most of the food waste is produced at the bottom of the food chain, including consumer-facing enterprises (grocery stores, supermarkets, institutional food services, restaurants) and households (Dou et al., 2018).

The leading countries worldwide in terms of food waste generation are the United States of America; China; the European Union; Saudi Arabia; and Australia. The annual food waste turnover of these nations is shown in Fig. 1 (Rajeh et al., 2021). This diversity is influenced by cultural norms, affluence, urbanization, and future outlook. Some social-cultural, gatherings require the preparation of a large quantity of food to demonstrate charity, wealth, and social position, but much of this food is squandered (Neff et al., 2015).

In India, food waste is in an alarming condition. A lot of food is spurt as waste from canteen, restaurants, hotels, family functions and weddings. As per a report by the United Nation development program, out of total food produced around 40% is wasted in India. Also, food waste worth Rs50,000 crore approximately is wasted every year in India according to the agriculture ministry. This huge amount of food waste also generates 3.3 billion tons of greenhouse gases that directly affect the environment. India tops globally in terms of wheat and rice production. Most of the part of this is either exported or consumed within the country but still, around 21 million tons of wheat produced is wasted every year. This huge amount of waste wheat can be used either as food for humans or can be converted into animal feed.

However, it must be emphasized here that food waste occurs in practically all metropolitan environments, whether it is in developed countries, developing countries or underdeveloped countries. Indeed, cities in poorer countries may produce more food waste than cities in developed countries, owing to insufficient recycling resources (Rajeh et al., 2021).

Innovations in the agro-food business are required to increase worldwide food and nutritional security, along with environmental sustainability and lower production costs (Georganas et al., 2020). When food waste is used for animal feed it not only reduces its cost but also results in increased profits for livestock farmers. An added benefit to this is the reduction of environmental concerns caused by the degradation of such wastes(Kaur et al., 2020). Together with the possibility to fill the shortfall in animal feed.

Additionally, apart from that, it will also assist in minimizing the negative environmental impact of food waste and loss by lowering a portion of the carbon footprint (Zutshi, 2018). Nonetheless, to reduce present food waste levels improved waste management strategies must be employed, but, there will be some food waste chance persists. Moreover, certain food products contain inedible components that will inevitably end up in the waste stream. Landfilling method is the most typical one to deal with food waste, but, it is environmentally harmful and dangerous to human health(Elliot et al., 2017; Toolkit, 2013).

2. Classification Of Food Waste

Classification of food waste categories that analyse the restrictions and possibilities for wastage valorization based on regulations and waste qualities are mentioned in Fig. 2. The classification is based on the source site of the waste and is explained below in brief.

2.1. Organic crop residue (Fruits and vegetables)

Fruits, collected vegetables, or grains, as well as processing by-products like pomace, straw, peels, husks, stones, stover, factory vegetable oil, and oleochemical residues, are all examples of organic crop residues, and they are rich in carbohydrate, lipids, sugars, and inorganic substances. Furthermore, phytochemicals like phenolics, carotenoids, and tocopherols, which have tremendous potential in the cosmetics, food, and pharmaceutical industries, can be found in large quantities in organic crop leftovers. Because the transportation and treatment of organic crop wastes are expensive, they can also be used as animal feed.

2.2. Catering waste

Catering wastes include leftovers from coffee shops, restaurants, pubs, and other food-related wastes that are not suitable for human consumption. Approximately 90 per cent of catering waste can be recycled or repurposed. They are rarely recycled because of cognizance, logistical issues, and the difficulty of segregating waste from their containers. Mixed garbage from meal preparation, wrapping, and separated debris, glass, organic, cardboard, plastic, or used cooking oil make up the majority of catering waste.

2.3. Animal by-products

The meat, fish, and poultry industries are responsible for most food waste. These wastes have a diverse composition, including intestinal residues, lipids, and blood, and are extremely polluting due to high COD (chemical oxygen demands) and BOD (biological chemical demands)levels (Poyatos-Racionero et al., 2018).

2.4. Packaging

Catering and household trash packaging must also be pretreated before recycling or winding up in landfills. Recycling rules have sparked a surge in interest in packing valorization (plastics, cans, papers, or glass), accounting for roughly 73 per cent of household garbage. Alternatively, domestic rubbish can be utilized to produce biogas through biodegradable waste fermentation (Poyatos-Racionero et al., 2018).

2.5. Domestic waste

Household or domestic trash disposal is an issue that is critical to any city’s administration. Cities that do not have an appropriate waste management system risk the spreading of disease and halt the economy. In wealthy countries, garbage is disposed of in sanitary landfills, which has worked successfully for a long time; however, in confined spaces, trash incineration and material recycling are often more likely to be used (Cecilia et al., 2019).

2.6. Industrial waste

Various organic wastes and related effluents are produced by food processing industries, such as chips, juices, confectioneries, meat, and fruits. These organic by-products can be converted into various sources of energy. The need for food and its applications develops in tandem with the world’s population. As a result, diverse food and beverage firms have sprung up in that region to accommodate the region’s

expanding demand for food (Girotto et al., 2015). Table 1 enlists different industries involved in food waste along with the percentage of food waste amount they generate.

Table 1
Estimation of waste in different food sectors (Segree *et al.*, 2011)

S. NO	Industrial sector	Amount of food waste generated in %
1.	Meat and meat product industries	2.5
2.	Fish and fish product industries	3.5
3.	Fruits and vegetable industries	4.5
4.	Dairy industries	3
5.	Grain industries	7.5
6.	Drink industries	2
7.	Fat and oil industries	7.5
8.	Other products	2

3. Recent Developments In Global Food Waste Generation

According to the UNEP Global Food Waste Report for 2021, food losses and food waste cost the industrialized world roughly 680 billion US $ and the developing world approximately 310 billion US $ (El Bilali and Hassen, 2020). Food is consumed in approximately equal amounts of 670 and 630 million tons in developed and developing countries respectively. Fruits, vegetables and roots and tubers have the highest rates of food waste of any food type(Joensuu et al., 2021). The FAO estimates worldwide food waste at 30% for grains, 40 to 50% for root crops, fruits and vegetables, 20 per cent for oilseeds, meat and dairy, and 30% for seafood. Consumers of developed and developing countries squander nearly 222 million tons of food every year, whereas underdeveloped counties like Sub-Saharan Africa generate only 230 million tons of food (Monica and Marius, 2013).

As per the FAO, food waste accounts for more than half of the world's yearly grain crop (2.3 billion tons in 2009/2010). North American and European consumers produce 95 to 115 kilograms of food waste per year per capita. Still, consumers in Sub-Saharan Africa and South and Southeast Asia generate 6 to 11 kilos per year per capita (Oelofse et al., 2018). In rich countries, total per capita food production for human feeding is around 900 kg/year, which is roughly two times (460 kilograms) of production in the poorest regions. Postharvest and processing expenses account for 40 per cent of overall losses in developing nations, whereas retail and consumer losses account for more than 40 per cent of total losses in industrialized countries. Food loss and waste constitute huge wastages, including water, land, energy, labour, capital, and the production of unneeded greenhouse gas emissions(El Bilali, 2018). Even if just a quarter of the food lost or wasted around the planet could be saved, that would be sufficient to feed the world's 870 million starving mouths. Food waste is rampant in developing countries because it occurs

early in the production chain due to a lack of suitable harvesting procedures, storage facilities, and cooling facilities (Bharucha, 2018). Food waste and loss can be decreased by strengthening the supplier base and investing in infrastructure, transport, and food packaging (Krishnan et al., 2020). Food is mainly discarded and wasted in later stages of the production process in middle and high-income countries. Table 1 shows the quantification of food waste in each food industry. Unlike in developing countries, consumer behaviour is critical in developed countries. Farmer-buyer agreements can assist in increasing coordination for decreasing the food loss at the time of crop buying by the industries or any end user(Dou et al., 2016).

Further, raising awareness among businesses, retailers, and buyers and identifying a suitable use for discarded food are practical techniques to reduce losses and waste of food. Food loss and waste account for over 30% of all food consumed worldwide (FAO 2015) (Vilariño et al., 2017). This translates to 1.3 billion tons of CO_2 every year. Food loss and waste also refer to the loss of resources such as water, land, labour, and energy used to produce food. Food is crucial in climate change because methane is created during the decay of abandoned food, and greenhouse gases are emitted during food production and distribution. Food loss and waste influence food supply chains as well, as it affects profitability for food producers, escalate consumer costs, and restrict access to food. Alleviation in food loss and waste could have a significant impact on food security and the environment(Cole et al. 2018). There is no consensus on how much global food production is lost, with estimates ranging from 10–50% (Katt and Meixner, 2020). The FAO(2011) estimates that 1.3 billion tons of consumable foodstuffs generated for people's use are wasted each year, accounting for one-third of global food output (Varese and Bonadonna, 2019). This is enough to lift one-eighth of the earth's population out of poverty (FAO, 2012) and relieve global impacts on food supply to satisfy a 50–70 per cent increase in demand by 2050. Moreover, FAO predicts that wasted or thrown food produces 3.49 billion tons of CO_2 or equivalent greenhouse gases across the supply chain. Based on current projections, the annual bulk-trade valuation of prepared and unconsumed food might also reach 936 billion US $, (Ioannou et al., 2022).

4. Sustainable Management Of Food Waste

In the past few years, the prospect of sustainable management of food waste bought new markets and opportunities. Previously the word “Food Waste Recovery” was not employed, although the term recovery emphasized the possibility of reusing or valorizing food waste (Plazzotta and Manzocco, 2019). The phrase “Food Waste Recovery” was coined in 2012 by the Integrating Safety and Environmental Knowledge Into (ISEKI) Food Association (FA) Special Interest Group (Galanakis, 2018). It has been used to shorten the word “useful compounds recovered from trash by-products”. The primary distinction between the commonly used terms “Food Waste Recovery” and “Food Waste Valorization” is that the latter indicates the quantitative and qualitative reusing of food losses within the food supply chain. By manufacturing high-value-added commodities, household waste restoration aims to improve chemical components depleted in food waste streams (e.g., functional foods) (Plazzotta and Manzocco, 2019).

5. Application Of Different Food Wastes

The industrial extraction of value-added chemicals from food waste began a few decades ago. Citrus peel is the first by-product of recovering flavonoids and essential oils and reusing them as additive agents in fruit juices and foods(Sharma et al., 2017). Several businesses have begun commercializing the most recent procedure in the last decade to convert this waste into valuable molecules. Whey cheese is the most intensively researched food by-product among animal-derived side streams and serves as the best example of valorization. The most common substances generated from this source are protein and various sugar derivatives, as evidenced by the numerous procedures and products that are commercially available. Around 50 firms across the globe now extract valued chemicals derived from waste food and commercialize them as clean label components for packed foods (e.g., natural preservatives to meet shelf-life standards, beneficial compounds), all without affecting aroma, flavour, or texture (Galanakis, 2018). Nevertheless, one key challenge that makes it difficult to incorporate food waste into animal diets is its nutrient unpredictability (FAO, IFAD, UNICEF, 2020). The sources of food waste and other characteristics related to consumers, including their ethnic origin, age profile, and dietary habits, have an impact on the nutritional content of food waste. Food waste has a high moisture content, ranging from 50 to 85 per cent, which reduces its shelf life and makes collection and incorporation into animal nutrition more difficult(Wang et al., 2021).

5.1. Remedies And Guidelines

Foods that are very perishable, like fruits, veggies, and animal-based products, lose key nutrients when lost or get wasted. Food loss contains a high nutritional value since its ingredients were designed for human food (Bordewijk and Schifferstein, 2019). It has been recommended that heat behaviour is necessary to create a healthy by-product of food to reduce moisture content. Bioactive chemicals are dietary compounds that promote health, showing a favourable effect on the human body, cells, or tissue. A range of chemicals found in plant-animal products has been shown to offer health benefits in humans. Bioactive compounds include long-chain polyunsaturated fatty acids (PUFA), polyphenols, carotenoids, vitamins, and peptides. Important examples of long-chain PUFAs include eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and arachidonic acid. Food waste originating from fish or meat may contain bioactive compounds since bioactive molecules are abundant in meat, fish and other animal products. Recently, modern animal agricultural producers and customers have been intensely engaged in generating healthy meat and related goods. Therefore, their usage in animal feeding can lead to the production of high-value items (Georganas et al., 2020).

Food waste assessment has been the subject to quantify food waste across the entire food chain. Researchers have looked into the amount and primary factors at the point of ultimate consumption, but the agricultural processing and retail stages are still unattended(Boschini et al., 2018; Caldeira et al., 2019; Fiore et al., 2017; Schneider et al., 2019; Secondi et al., 2015; Thamagasorn and Pharino, 2019). Reduced food waste has been recognized as a serious priority for ensuring a sustainable food future worldwide. Goal 12 of the Sustainable Development Goals focuses on responsible consumption and

production and includes two indicators to track global food loss and waste (to reduce it) (Nakai, 2018). In the United States, the Department of Agriculture and the Environmental Protection Agency launched the U.S. Food Waste Challenge on June 4, 2013, inviting entities to participate from all parts of the food supply chain, including agricultural processors, farmlands, food producers, supermarkets, cafeterias, higher education institutions, colleges, and local governments (Food Waste FAQs, 2017).

In order to cut down on food waste, it is important to improve the manufacturing, marketing, shopping/ ordering, storage, and preparation processes. Second, integrate food donors with non-governmental organizations and hunger relief organizations like pantries and food banks to cut down on wasted food. In addition, composting, biofuel production, and the production of natural fertilizer are all viable options for dealing with food waste. Both agencies also announced a nationwide food waste and loss objective for the first time on September 16, 2015, aiming to reduce 50% before 2030 to improve food security and preserve natural resources significantly. The National Resources Defense Council released a summary report with recommendations for reducing waste during the food supply chain (Gunders, 2012). Following are some key points to consider-

- Local recycling programs and food waste prevention and education activities can be integrated by state and local governments. Farmers who contribute excess crops to local food banks may be eligible for government tax benefits. California, Arizona, Oregon, and Colorado have already enacted the proposed legislation.
- Restaurant chains, supermarkets, and institutional food services may evaluate their food waste and put best practices in place. Restaurants can provide lesser amounts and donate unsold supplies and cooked food to charities. Schools may explore innovations that permit children to prepare their meals to reduce food waste, such as salads or other bread foods.
- Farmers can assess food wastage throughout distribution, processing, and preservation and implement exemplary practices. Farmer's marketplaces may sell "unappetizing" production, which consists of abandoned, malformed vegetables and fruits that do not match the conventional aesthetic values. Farms can offer fresh but unmarketable products to food banks at a lower price.
- Customers can learn to prepare and store food appropriately, and discard it when foodstuff is no safer or edible

The EPA offers the "Food Recovery Hierarchy" image to demonstrate how to manage surplus food (US EPA 2020). From top to bottom, most favoured to least preferred (Figure.3), the methods include *Source reduction*: The first prevention is to reduce the total amount of produced food

1. *Feed hungry people*: Providing surplus food to community centres for donation
2. *Feed animals*: Food wastes and leftovers are donated to nearby farmers who may utilize them as animal feed
3. *Industrial uses*: Leftover oils, fats, and grease will be used to produce biofuel.
4. *Composting*: Food scraps that have been composted to generate organic matter can then be utilized as a source of fertilizer for the soil.

5. *Landfill/Incineration*: Last option for food that has been wasted. The food waste is destructed either by burning or dumped into landfill sites (Ceryes et al., 2021).

While government assistance is required to reduce waste, people also play an essential role. On a more personal level, there is a lot that we can do to reduce food waste. Here are some practical strategies for reducing food waste. Make a diet plan and a shopping list to figure out what you need. According to previous research, around 20% of what we buy in urban India gets thrown away. You might reduce the surplus and minimize waste. Purchase in the quantity that you can utilize. Avoid impulsive purchases since they will almost certainly end up in the trash. If you're cooking at home, be sure you don't overcook anything. If you accidentally make more food than you can eat, don't throw it out. Feed someone in your community who is hungry.

Use green veggies first to avoid spoilage. Don't toss out fruits and vegetables that have purely cosmetic imperfections. Use canned and bottled foods before their expiration dates. Ask your office canteen how they handle the excess food. Cooked food, which has a short shelf life, must be handled more quickly. Contact NGOs that convey extra food to the needy. Also, whether you hold a party at a resort or host a family get-together at home, make sure that your leftover food is delivered to a community like an orphanage or an old age home (Morone et al., 2017). Food waste can be reused in many aspects, which is summarized in Fig. 4.

6. Use Of Food Waste In Animal Feed Production

Global food waste amounts to 1,3 billion tons or three times the amount of food that is produced. It is commonly alluded to as "food waste" when food fatalities occur in the final segments of the food supply chain, particularly regarding retail and ultimate ingesting. In contrast, it is commonly called "food loss" when food losses occur during the food supply chain's production, post-harvest, and processing stages. The nutrients in food are among the most squandered resources, making food waste a foremost problem. The term "food waste" refers to throwing away perfect nutrients earmarked for human use and therefore, usually have an excellent nutritional value. Early and intermediate phases of food supply chain losses in underdeveloped nations far outweigh the food waste that occurs in retail and final consumption, informing us that most food spoilage happens throughout manufacture, handling, and warehousing. Preventing food wastage is essential, but reintroducing food scraps into the food supply chain is a necessary component of the circular economy, which sees trash as a valuable resource (Georganas et al., 2020).

Overwhelming attention is being paid by researchers worldwide to processing back food waste and surplus fruits and vegetables into the food chain by transforming them into animal feed. Since time immemorial, livestock producers have relied on feeding food waste to their animals in place of more conventional feed grains or protein sources (Westendorf, 2008). By repurposing food waste, livestock farmers can lower the cost of animal feed, resulting in increased earnings for themselves. Additionally, reducing environmental concerns caused by the degradation of such wastes is a significant positive

outcome. In addition to the benefits indicated above, commercial food waste as animal feed comes with several drawbacks, such as a lack of safety, inconsistent nutrient profile, and expensive manufacturing costs. High water content in food waste makes it susceptible to decay during collection, transit, and storage. Thus, the quality of animal feed produced from food waste is subjected to degradation during the collection, transportation, and storage of the waste. Additionally, the volume and consistency of commercial food waste (namely, from the food retail and service industries) are not always consistent, and the nutritional composition of the trash is not always uniform. However, producers of recycled animal feed have surmounted these challenges through innovative thinking, and they have successfully recycled food waste into animal feed at a reasonably low cost (Nakaishi and Takayabu, 2022).

Particle solids from the waste solids separation process might be used in animal feed. Dried or pelleted food waste can be generated from these products and marketed as animal feed. Meat and poultry production waste has long been and will continue to be utilized as animal feed. Animal feed often contains a combination of blood, feathers, and bones that have been processed into a meal. Leftover cuts of meat deemed unfit for human consumption are either marketed to third-party rendering operations or transferred to such facilities directly for processing into animal and pet meals. The utilisation of these resources leads to environmental and business benefits. This is due to the fact that their marketing places them in competition with other fats, vegetable oils, and proteins (Westendorf, 2008).

Table 2
The different methods used for conversion of food waste into animal feed

Method used	Microorganism used	Food Waste	Reference
Solid state fermentation	*Neurospore intermediate*	Bread wate	(Brancoli *et al.*, 2021)
Fermentation	*Saccharomyces cerevisiae* and *Lactobacillus reuteu*	Lemon peel and non-sterilized fish waste	(Tropea *et al.*, 2021)
Fermentation	*Bacillus subtilis, Aspergillus niger Lactobacillus reuteu*	Pomace of fruits and olives	(Munekata *et al.*, 2021)
Ruminal fermentation	*Lactobacillus Casei*	Seasonal fruits	(Panyawoot *et al.*, 2022)

Food scraps and other forms of garbage have long been used to supplement animals' diets, particularly those kept on farms, which is an ancient practice. According to FAO, 30 per cent of cattle feed worldwide is trash from food supply chains or by-products from growing and processing food. However, a substantial amount of new food might be appropriately used for animal feed rather than being thrown away in landfills, where it would add to the greenhouse effect by generating methane. This would be a more environmentally friendly option. More circular systems that reuse nutrients for feed can also assist in reducing other significant environmental impacts of producing feed crops, such as land, energy, and water use, while also improving food security by reducing food waste and increasing food output. Despite its apparent simplicity, reinstating food waste into the food chain is not without obstacles. Farmers must determine the best feed option for their livestock, and it must always be accessible and affordable. The

environmental effects of reintroducing this waste into the food chain and the benefits and costs involved must also be considered. To maintain sustainability in the cattle industry this can be quite a good strategy to convert “waste into possibilities for development”(Wadhwa and Bakshi, 2013)

6.1. Mechanism of conversion of food waste into animal feed

Toxic waste from fruits and vegetables includes tomato pomace, bottle gourd pomace, citrus pulp, carrot pulp, baby corn husk and fodder, cabbage, cauliflower leaves, pea pods, pineapple waste, pineapple bran, and other ingredients. Due to high moisture (80–90 per cent), total soluble sugars (64 per cent), and crude protein (10–30 per cent) contents, food waste are highly fermentable and prone to decay. When production or processing is at a high rate, large quantities of these resources are abundantly available. They cannot be used at the same rate as they are produced, resulting in overproduction and environmental pollution. Appropriate conservation methods should be developed to guarantee that these resources can be given to livestock throughout the year, particularly during the low period of green fodder production (Wadhwa and Bakshi, 2013).

6.2. Conversion technologies for food waste to animal feed

There are majorly three food waste treatment technologies that have been identified i.e. wet, dry, (Fig. 5) and ensiling/fermenting procedures (Fig. 6). A simple heating stage is involved in wet-based systems, which provide feed with 70–80 per cent moisture content. Compared to dry-based feeding, wet-based feeds required minimum preparation time. They can, however, last only a few days if not refrigerated, and shipping costs can be prohibitive. Wet-based feeds are rarely transported long distances but instead fed to animals in the feed-producing plants’ vicinity. Dry-based approaches entail drying food waste to a less than 20% moisture percentage. Dry feeds have a longer shelf life and a smaller bulk volume than wet feeds due to their low moisture content, making them more manageable and less expensive to store and transport. They are also simpler to incorporate into diet regimens (Rajeh et al., 2021). Spoiled, small-sized bananas, banana peels, apple pomace (the residue remaining after the juice has been squeezed out of the fruit), and vegetables such as fresh potatoes and pineapple crowns can be used as animal feed, (Wadhwa and Bakshi, 2013). Table.3comprehend different types of waste and the types of animal feed that can be made out of it. Avoid composting or discarding them in landfills and rivers to dodge environmental damage. As an alternative to such disposal methods, materials can be recycled for animal feed or further processed to extract or manufacture value-added items.

Table 3
Types of food wastes and their conversion to animal feed.

Type of waste	Constituent	Animal Feed	References
Apple Pomace	7.9% crude protein 5% Ether 1.86 ME*/kg 1.06–1.12 ME*/kg	Milking cows Broiler	(Ajila et al., 2015)
Banana peels	8% protein 6.2% Ether 4.8% phenolic 13.8% soluble sugars	Pigs Rabbits	(Girotto et al., 2015)
Citrus Pulp	10% protein 7% Ether 55% soluble sugar Up to 40% soluble fibres	Lambs Cows Lactating Ewes	(Fegeros et al., 1995)
Carrots	10% protein 1% ether 60% soluble sugar 200–1000 mg/kg beta carotene	Laying hens Rabbits Rahmani sheep Piglets	(Steenfeldt et al., 2007)
Potato	80.5% starch 10.5% protein 0.4% ether	Lactating Cows Beef Cows Cooked potatoes for pigs	(Halliday, 2010)
Corn husk	15% protein 1.8% ether	Adult buffaloes	(Bakshi et al., 2017)
**ME: Metabolic Energy*			

7. The Success Story Of Food Waste Into Animal Feed.

The problems of food waste management and insecurity could be solved at the same time by using food scraps as animal feed because they are cheap, abundant, and sustainable Consumer and business

support, legislation change, and investment in food waste collecting infrastructure are necessary for the extensive and feasible implementation of the conversion of food scrape into livestock feed. However, food waste is being used as animal feed globally, especially in modern pig production methods. Food waste can be recycled as an animal feed with the help of heat treatment, which is done in countries like Japan and South Korea, where 35.9% and 42.5% of food waste are used. There is strict legislation governing the heat treatment, storage, and transportation of food waste feed in this facility (Salemdeeb et al., 2017).

Increased interest in the prospective relegalization and the cost of standard pig feed has risen and become unpredictable, as a result, a large number of people are advocating for the use of food waste as a substitute. Another reason behind using food waste as animal feed is the increased concern about the environmental impact of grain- and soybean-based diets, according to a recent report. Approximately one thousand two hundred animal feed practitioners from food industries, research, and NGOs participated in a recent study that recognized the usage of food waste as a concern for sustainable animal nutrition research. The concern about the sustainable animal diet raised several questions. Animal feed and feeding are at the very heart of livestock operations. The animal diet produced from food waste impacts animal growth, animal health and welfare, product quality and safety, producer income, household security, land usage and land-use change, water pollution, and greenhouse gas emissions. It also directly or indirectly affects the entire animal farming and its related services. Feasts are a vital part of animal husbandry, regardless of species or method of manufacture, accounting for up to 70 per cent of total production costs. Animal diets must be sustainable to support the long-term viability of livestock production across all production systems (Makkar and Ankers, 2014).

To make the idea of sustainable animal feed from food waste, it is imperative to focus on the fulfilment of factors like a good gross profit, ways, and processes that are not harmful to our planet and natural resources. The manufacturing process at any stage should not challenge or violate the ethics of any community or culture. The monetary aspect cannot be overlooked to make the large-scale conversion of food waste into animal feed. Profitable and economically cheaper animal feed produced using waste food will attract the market. To successful manufacture, nutritively balanced and safe animal feed for livestock, the significant issue of ethical conflicts and cultural sentiments needs to be tackled cautiously. The four pillars of successful and practical sustainable animal feed are shown in Fig. 7.

Conclusion And Future Prospective

Food waste will remain a problem in consumer markets, but adequate management is crucial. Animal feed and soil nutrients could be generated from the proper management of food waste. There are a number of studies that need to be conducted to identify which foods are being wasted to improve food waste processing. This presents issues associated with the cyclical nature of food waste. Food waste and the factors listed above are influenced by seasonal changes which necessitate food waste measurement The findings of the present study prompted more inquiries. Efforts to take into the justification of the future positive effects of food waste on the environment should be investigated. While

preventing food waste, one should always take precedence, any leftovers should be used in a closed-loop system rather than dumped in a landfill. When governments participate in food waste diversion as a component of larger infrastructure enhancements to create a more circular and lower-impact food system, waste-to-feed paths should be investigated.

With the surge in the human population, the petition in the food supply also increased. This demand also results in a large amount of food spoilage. More than one-third of the food produced is wasted all over the globe. This review elucidates the utilization of food waste in animal feed and explains the application of food waste in different sectors. Generally, food that is wasted contains a high nutritional value. Appropriate technologies were required to convert food waste into animal feed without losing its nutritious weight. Food waste as animal feed provides a better way to solve waste management and food security issues that burden the environment and can be added to animal diets without affecting the growth performance of the animals. Through regular sampling methodologies and detailed nutritional assessments, upcoming research should explore the heterogeneity in the nutrient content of food losses and wastes.

Furthermore, stakeholders must build better garbage pickup, transportation, and management procedures, as these are complex parts of industrial recovery feed manufacturing. There is an urgent need for research and development in technologies for the conversion of food waste into more nutritious and economic animal feeds and other useful products. The developed procedure will enable the generation of data that will be crucial in allowing the commercial inclusion of waste-based animal feeds to end users. In the future, incorporating low-cost food waste-derived items into animal diets will provide the opportunity to reduce production expenses, which account for a significant portion of overall poultry and swine production costs. If safety and quality are assured, this could be a strong motive for people in the business world to get involved with using food waste as animal feed. Finally, reusing food waste in animal feeds may help to reduce food security and environmental challenges.

Declarations

Ethical Approval

Not applicable.

Consent to Participate

Not applicable.

Consent to Publish

Not applicable.

Author Contributions

All authors contributed to the study conception and design. Ziaul Hasan had the idea for the article. Muneera Lateef performed the literature search and data analysis. Ziaul Hasan and Muneera Lateef both drafted and critically reviewed the work. All authors read and approved the final manuscript.

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Competing Interests

The authors have no relevant conflicts of interests to disclose.

Availability of data and materials

The authors declare that the data and materials used in the manuscript are available for public domain.

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Figures

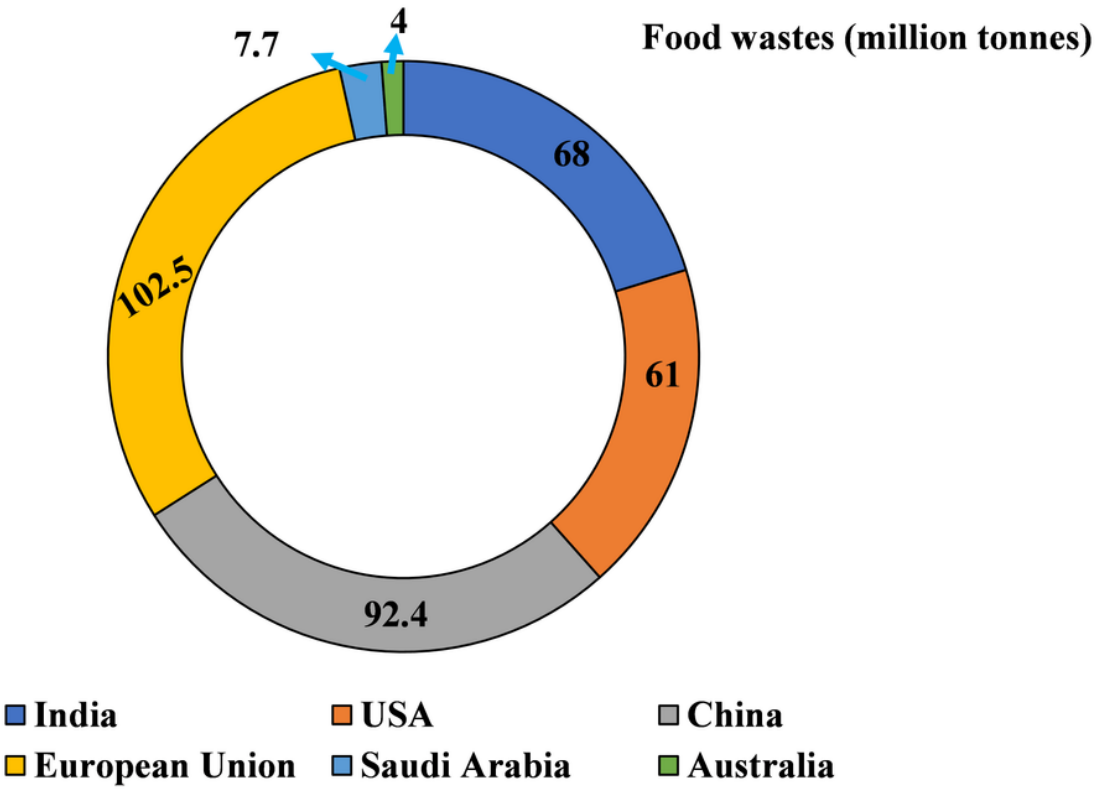

Figure 1

Food wastes generated in different regions of the world

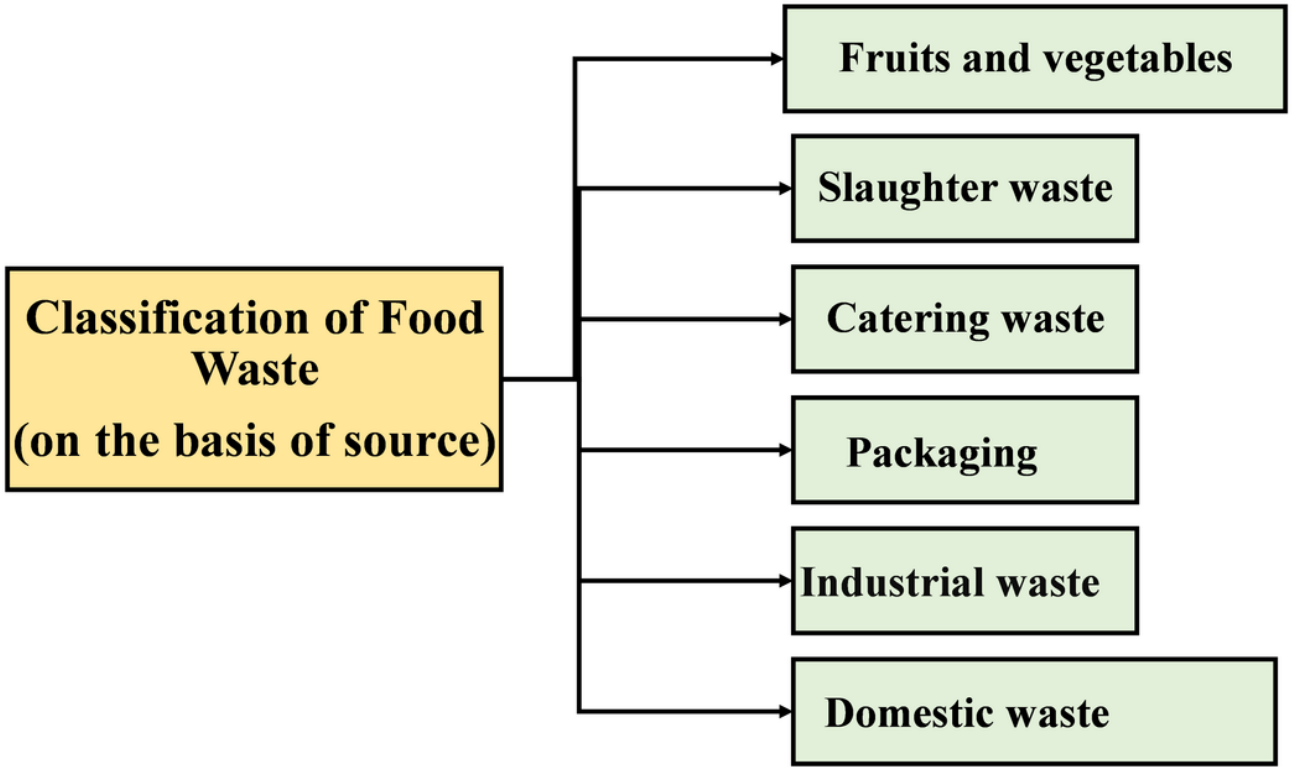

Figure 2

Classification of food waste types

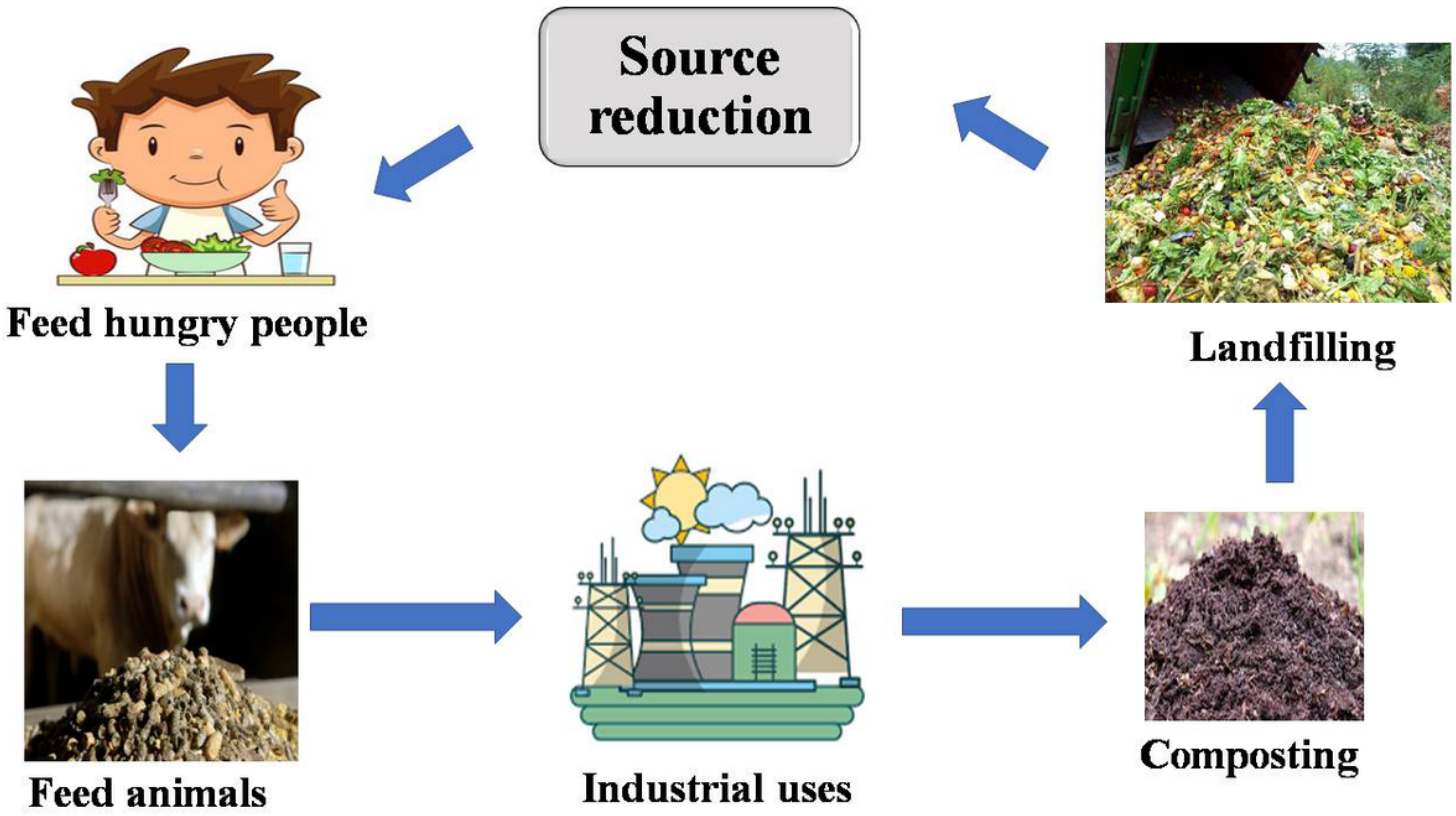

Figure 3

Food Recovery Hierarchy graphic to explain ways to handle the excess food

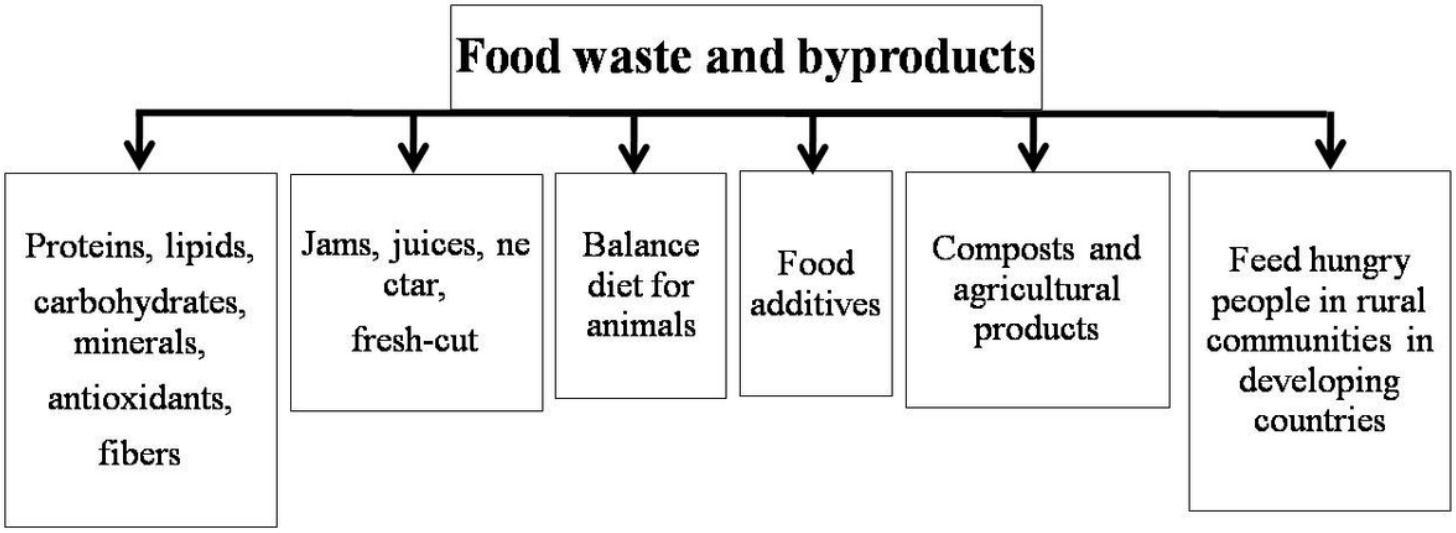

Figure 4

Application of food waste in different aspects

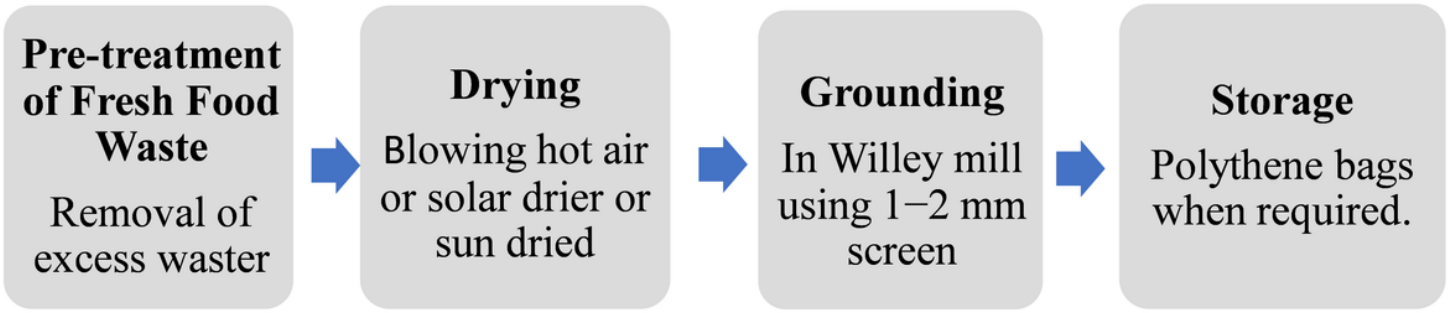

Figure 5

Process of fruit and vegetable waste conversion using drying method.

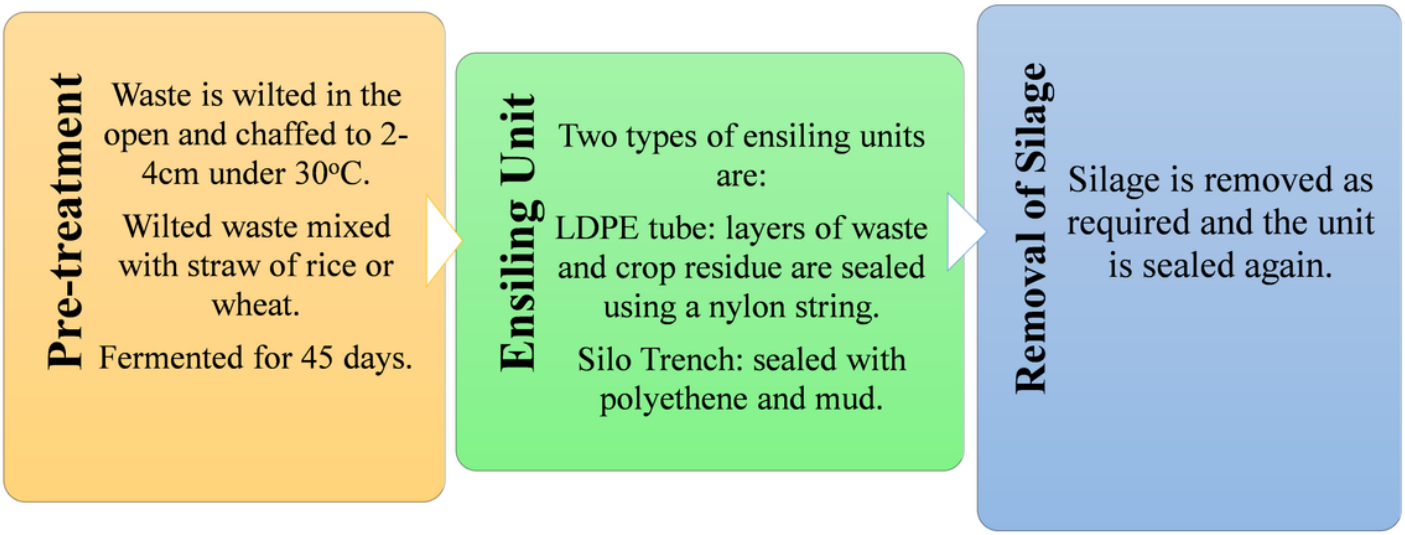

Figure 6

Process of converting fruit and vegetable waste using ensiling bunkers or silo trench.

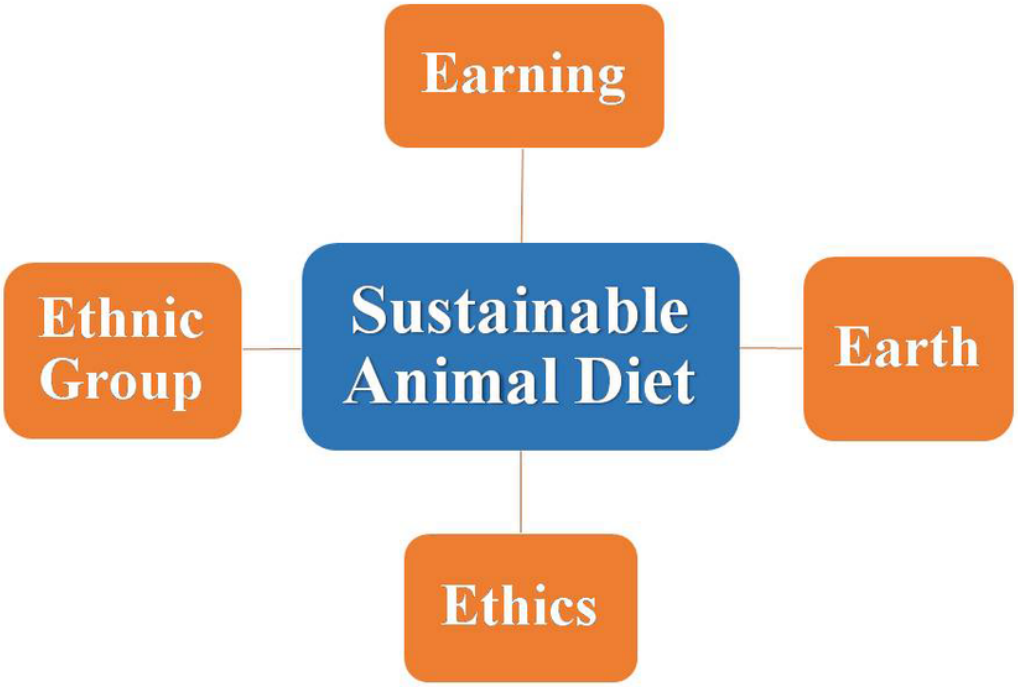

Figure 7

The ideal structure of a sustainable animal diet.