**Food waste for livestock feeding: A step towards sustainable food waste management**

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**Abstract**

Food waste is inextricably related to the rising challenges of food security, resource and environmental sustainability, and climate change. In develop countries the majority of food waste happens during the consuming stage, at the end of the food chain. There are significant limitations to the current methods for handling the wasted food. Livestock have historically served as bio-processors, converting undesired or inedible dietary ingredients into meat, eggs, and milk. Food waste can be transformed into safe, nutrient-dense, and value-added feed products with the aid of modern treatment technology. A practical outcome that concurrently tackles the problems of waste management, food security, resource conservation, pollution, and climate change mitigation is the recovery of consumption-stage food waste for livestock feeding.

 **Key words:** Food waste, Food security, Livestock

1. **Introduction**

Any strategy for sustainable livestock development must focus on making efficient use of the feed resources that are available, including reducing food waste and developing alternative feed resources that do not compete with human food. Livestock production is a key component of agricultural growth in India. The growing unborn demand for livestock products, driven by increases in income, population, and urbanization, will place a massive demand on feed resources. In addition, the sustainability of feed production systems is under stress due to the depletion of natural resources like land, soil, and water, food-fuel-feed competition, global warming, and inconsistent climate change. A shortage of roughly 35.0, 30.0, and 48.0 percent of dry fodder, green fodder, and concentrates, respectively, results from the increase in the number of Indian cattle. By 2030, it is anticipated that more than 100 million tonnes of waste produced each year from the dairy, fish, poultry, meat, and fresh and processed fruit and vegetable industries will not be profitably recycled as animal feed. Furthermore, a significant amount of these pollutants are disposed of in rivers or landfills, endangering the ecosystem. Only 30% of the world's population is expected to produce the enormous quantities of fruits, vegetables, and animal products that urban dwellers require by 2050, when 68% of people are expected to live in urban areas (Elechi et al. 2022). India faces a significant challenge in reducing food loss and waste, as it must feed its rapidly expanding population (1.7 billion by 2050) (Murillo-Roos et al., 2022). Three times as much food is wasted annually (1.3 billion tonnes) (Koul et al., 2022). Farmers can increase their income by using food scraps to reduce the cost of animal feed, and another important benefit is the reduction of environmental problems caused by the decomposition of such wastes. Therefore, a workable plan is imperative in order to recover and effectively use the waste generated from various food sectors to economies on livestock feed and also reduce the environmental pollution associated with their conventional disposal.

**2. Reusable food waste from various industries**

The amount of food wasted at the end of the food chain is referred to as food waste (FW). Retailers and consumers suffer losses as a result of this food loss, which also results in the loss of resources employed in the production cycle, including labor, energy, water, and land (Ishangulyyev et al 2019). According to various estimates, the food industry generates 69 million metric tons (Mmt) of fresh waste annually, including 50 kg of food waste per capita, in addition to over 500 Mmt of farm waste. It provides an excellent compass for creating value addition in supplements and animal feed. Furthermore, additional by-products and trash are probably going to be produced as the processing of cereals, pulses, oilseeds, fruit, and vegetables for value-added food products for human consumption increases. There is around 30 million tons of this type of food waste in India (FAO, 2019). India is the world's second-largest producer of fruits and vegetables (FAO, 2019). A significant amount of fruit and vegetable waste is produced as a result of the cropping pattern gradually shifting from cereals to profitable fruits and other horticultural crops. The majority are either disposed of in landfills or composted, which contributes to the contamination of the environment. However, these unconventional resources can serve as a great supply of nutrition for farm animals.

Meat yield from animal slaughter is just 30% of the entire weight; the remainder is wasted and goes as byproducts. Typically, these wastes—such as trimmings, inedible fat, blood, feathers, ruminal content, bones, egg shells, etc.—are utilized to make fertilizer, biogas, medications, pet food, and cattle feed. Moreover, these waste products are typically transformed into intermediate products like di-calcium phosphate (DCP) or meat cum bone meal (MBM), which are subsequently combined with different feed ingredients to serve as feed supplements for fish, poultry, and pets like dogs and cats. As a result, the establishment of facilities for the exploitation of waste and by-products in the manufacturing of animal feed has enormous potential. Table 1 summarizes the various food waste-generating industries and the percentage of food waste they produce. Table 2 shows the amount of food waste produced per capita by nation.

 **Table 1 -** Food waste estimation in various food industries (Hasan and Muneera, 2022).

|  |  |  |
| --- | --- | --- |
| **SN**  | **Name of Industrial sector** | **food waste produced** |
| 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% |

 **Table2.** Food waste produced by the country and households

|  |  |  |  |
| --- | --- | --- | --- |
| Name of Country  | Study region  | Waste (kg/Capita) | Reference |
| India  | Andhra Pradesh | 58 | (Ramakrishna, et al 2017) |
| Pakistan  | Gujranwala | 88 | (Sahoo, et al 2022) |
| Australia  | Nationwide | 102 | (Arcadis et al 2019) |
| China | Urban China | 150 | (Zhang, et al 2020) |
| Japan  | Nationwide | 64 | (Diana,et al 2022) |
| United States of America  | NS | 59 | (Furbeck et al 2022) |
| Saudi Arabia  | Nationwide | 105 | (S.S.F. Food Loss & Waste Index 2019) |
| South Africa  | Nationwide | 134 | (Ramukhwatho, 2016) |

1. **Different types of Food waste (FWs) used for animal feeding**
	1. **Dairy Waste**

Every year, more than 1.2 million tons of residues (whey, ghee, and butter serum) are produced by the rapidly expanding dairy industry. The problems of employing them as animal feed include economic feasibility, collecting and distribution logistics, feed safety, and regular nutritional quality assessments. Heat sterilization, drying, and ensiling are some of the tactics that can be used, with or without the addition of fermentation aids such as bacteria and enzymes. Utilizing these dairy industry byproducts can reduce the cost of feeding the animals. Skim milk and butter milk, which were long considered by-products of the business, are now regarded as value-added goods and sold at the same price as milk. Whey, buttermilk from churning butter, ghee residue, and butter serum from pre-stratification of ghee production are examples of by-products that are produced in huge numbers but are not properly used. Calf and monogastric animal diets can effectively use the waste from skimmed milk powder. When making cheese, paneer, and chhana, a significant amount of whey is produced. When making cheese, paneer, and cottage cheese (chhana), about eight liters of whey are made for every ten liters of milk. About half of milk's solid content, or 6%, is found in whey, and some of its components, like whey proteins, have great nutritional value. There are now technologies that employ this by-product to make whey powder and whey protein concentrates.

Whey not only reduces the amount of water needed to produce beverages and baked goods, but it also gives them more nutritional value. Moreover, lactose, a key component of whey, is imported into India. This also allows whey to be used to produce lactose, which lowers the need for imports. Antioxidants and nutrients can be found in ghee residue. Its brown color and nutty flavor make it an excellent component for making baked goods like cookies and biscuits. A straightforward intervention can assist in turning it into nutrient-dense food products with added value. Typically, buttermilk and butter serum from the churning process of butter and the pre-stratification method of manufacturing ghee are wasted, but they can be successfully combined with curd to make buttermilk and lassi.

**2.2 Processed Food Wastes**

The use of food wastes is limited by the following factors: (i) the acidity of some foods; (ii) the presence of spices and condiments (such as masala), which slow down the growth of food-grade organisms and increase the proliferation of spoilage organisms; (iii) the combination of a wide range of food materials, such as fried, baked, steamed, and raw, and their variable combinations, which makes it difficult to standardize feed stock; (iv) challenging to balance the solid to liquid ratio; and (v) a nitrogen deficiency. The best bacteria to treat food waste for poultry and other agricultural animals are lactic acid bacteria (LAB). The feed may have low, medium, or large populations of LAB, depending on the situation. Urban hotels, weddings, and other gatherings that serve a lot of people raise severe concerns about how to dispose of food waste without harming the environment. Over 940 tonnes of food are wasted annually during marriage ceremonies in Bangalore, according to one case study. A portion of the edible components of this food waste can be recycled to feed the hungry with careful planning and execution, while the remainder can be used to make fertilizer/compost, pharmaceuticals, cosmetics, animal feeds, biodiesel, or natural gas through anaerobic digestion. Insects like black soldier flies can be raised from food waste, and they can then be used as protein-rich feed for fish and fowl. Furthermore, there is a possibility of reusing this waste in the food packaging sector by using expired packed food materials for insect farming. There are currently no regulations in place to prevent this waste. Many sectors of the food processing industry require policies for the responsible management and disposal of food waste.

**2.3 Meat Processing Wastes**

In order to stop environmental contamination and the spread of illness, meat processing facilities must have an adequate waste disposal system. Currently, the liquid waste from slaughterhouses is transferred to water bodies or the municipal sewer system, putting both terrestrial and aquatic life as well as public health at risk, while the solid trash is collected and disposed of in landfills or open spaces. Waste water from slaughterhouses has a chemical makeup that is comparable to municipal sewage, consisting of 55% suspended organic matter and 45% soluble organic matter. Approximately 375,000 mg/L of chemical oxygen is required by blood, which is one of the main dissolved contaminants in effluent from slaughterhouses. The majority of developing nations lack a systematic plan for getting rid of the liquid and solid waste produced in slaughterhouses. Due to its perfect amino acid balance and high protein content (around 17%), animal byproducts, especially blood, are regarded as liquid meat. According to Porselvam and Srinivasan (2017), anaerobic co-digestion is a practical treatment method that can be used to use meat processing waste. The composition and storage stability of chicken feed were examined by Karthik et al. (2010), who found that dry rendering is a safe way to eliminate germs in the raw material and create high-quality dog foodby adding used hen meal.

**2.4 Aquatic food wastes**

It is anticipated that 15 million tons of fish will be produced in India in 2020–21. Between 30 and 55 percent of the materials produced by domestic fish markets and fish processing are waste. India generates 3 million tons of trash annually on average, which is equal to 21% of the country's total fish production. Important nutrients like proteins, fats, minerals, and vitamins can be found in fish feces. Therefore, a variety of beneficial compounds, including chitin, collagen, keratin, PUFA, proteolytic, chitinolytic, and collagenolytic enzymes, as well as amino and carboxy peptidases, can be produced from aquatic waste. The secondary fish processing industry faces several significant challenges, including a lack of baseline data on the availability and quality of aqua waste, the fragmented nature of the domestic fish waste market, low-quality raw materials, a lack of cold chain facilities, a lack of domestic processing plants that meet desired quality standards, a lack of industry-research institution partnerships, and a lack of appropriate policies. Secondary fish processing can be encouraged to create industrial and formulated products, as well as high-value and specialized compounds. The Central Institute for Fisheries Technology (ICAR-CIFT), Cochin, has developed a number of technologies, such as lipid-based products (body oil, liver oil, PUFA concentrate), minerals (fish bone calcium), specialty products like chitin, chitosan, chitin derivatives, hydroxyapatite, astaxanthine, and squalene, and edible value-added products (battered/breaded products, pickles, and soup) made from fish waste. The following steps must be taken in order to process fish waste properly:

* Organizing trash utilization awareness programs around the country.
* Creating a nationwide database on secondary raw aquatic material availability at different hotspots.
* Finding promising technologies that are available from different organizations, such as CIFT, for setting up technology demonstration centers and expanding them to handle aqua waste and create high-value goods.
* Various government-backed programs to assist the aforementioned measures.

**2.5 Fruit Wastes**

In 2020–21, India produced more than 103 million metric tons of fruits. Only about 2.2% of fruits are currently processed commercially, which is a very low percentage. Fresh fruits and vegetables produce more than 60 million tons of trash every year because they are perishable. Aggregation and segregation, perish ability, seasonality, logistics, mixing with plastic, and trash from the home sector are some of the difficulties in turning horticulture leftovers into feed. Mechanized ensiling, economical and energy-efficient methods of moisture removal and densification, and successful anaerobic fermentation of the biomass are some of the engineering interventions for processing. The following section discusses several significant fruit waste examples.

**Pineapple waste:** Crowns, peels, cores, fresh trimmings, and pomace are all considered pineapple waste after post-harvest processing, and they make up around 30–35% of the fresh fruit weight. Pineapple bran, the solid residue left over after pressing macerated skins and crowns, is another waste product. Animals can be fed the wet bran fresh or it can be ensiled. Although pineapple waste is very low in minerals, it does include pectin, 40–75% soluble sugars, 60–72% fiber, and 4–8% crude protein. Pineapple waste can be ensiled after being combined with rice straw, hay, or wilted grass. Lambs given a total mixed ration (TMR) consisting of either pineapple waste silage or maize in a 62:38 ratio along with concentrate mixture showed similar performance, serum biochemical and mineral profiles, and nutrient utilization in a 75-day field trial (Gowda et al. 2015). When ensiled pineapple waste was used in place of green fodder in a crossbred cow fed TMR, a substantial improvement in milk output was observed in another 90-day feeding trial. In addition to lowering feeding costs, ensiling pineapple waste also assisted in solving thedisposal issue. Utilizing leftover fruits and vegetables (FVWs) in animal diets can save animal feed costs and boost livestock farmers' profits. Additionally, by reducing the conflict between food and feed, these non-traditional feed resources are a good substitute for maize and perhaps other feed ingredients that compete with human food. Antioxidants, pigments such as carotenoids, lycopene, polyphenolic compounds, pectins, anti-carcinogenic chemicals, essential oils, and bioenzymes including α-amylase, hemicellulase, and cellulase, lignin, manganese peroxidase, and laccase are all abundant in several FVWs. The presence of heavy metals, pesticides and their residues, alkaloids, mycotoxins, and anti-nutritional factors are some of the main obstacles to the use of FVWs. High dietary concentrations of these substances can have a negative effect on the health and welfare of animals. Animal products may include certain harmful substances, which could have an impact on human health. Before the FVWs are employed in animal feed, it is recommended that the possible hazardous substances be regularly monitored and tested.

**Citrus waste:** Up to 10% of the citrus pulp is made up of seeds, 30–35% internal tissues, and 60–65% peel. Citrus pulp degrades quickly and can pollute the environment because of its high moisture and sugar content, as well as the presence of mold and yeast. Therefore, it needs to be ensiled or sun-dried and pelleted to boost density. Five to ten percent crude protein, six percent ether extract, ten to forty percent soluble fiber (pectins), fifty-four percent water-soluble carbohydrates, and trace elements are also present. Due to its excellent organic matter digestibility (85–90%) and energy availability for nursing dairy cows, dried orange pulp is included in concentrate diets as a cereal substitute. In lactating dairy cattle, 20% concentrate can be substituted with dried citrus pulp. KW, or kinnow mandarin waste, made up half of the kinnows that were processed. Barley grains could be up to 50% replaced by KW in concentrate mixtures without compromising microbial biomass generation, VFA production, ME availability, or nutrient utilization. In a tube silo, fresh KW and wheat straw (WS) were combined in 75:25 ratios and then ensiled for 42 days. Buffalo calves' blood profiles, urine purine derivatives, and N-retention were all unaffected by feeding them KW-WS silage-based TMR.

**2.6 Waste from Vegetable**

In 2020–21, India produced more than 197 million tons of vegetables. Future growth in output will make approximately 32 million tons of different vegetable wastes and by-products available for use as animal feed. Here are a few of the main things that make up the majority of these: Baby corn leftovers: Both raw and cooked baby corns are consumed. The average amount of baby corn produced in India is between 7.5 and 8.7 tons per hectare.

Husk and silk (5.56 tonnes/ha), stalks and leaves during harvest (30 tonnes/ha), and male buds (3.13 tonnes/ha) are the by-products/wastes produced from baby corn (FAO, 2019; Mani et al. 2019; Bhattacharjya et al. 2019). These leftovers and by-products offer similar or higher nutritional value to maize fodder and can be fed either fresh or after ensiling. Aside from selling baby corn cobs for human consumption, farmers can earn extra money by selling baby corn fodder from the baby corn plant.

**Carrot by-products:** These consist of carrot culls, carrot tops, and carrot pomace following juice extraction. Cattle prefer and eat cull carrots because they are more appetizing. On a dry matter basis, fresh carrots have up to 60% sugars, primarily sucrose, 1.4% ether extract (EE), and 10% crude protein (CP), making them very pleasant and easily digested. Carotene and vitamin C are abundant in carrots. Horses may eat carrots as a staple food.

**Bottle gourd pulp:** The residue left over after the juice is extracted is known as bottle gourd pulp. Bioactive substances such as 2,2-diphenyl-1picrylhydrazyl-hydrate (DPPH), vitamin C, flavonoids, and total phenolics are also abundant in it. Once it has dried in the sun, it can be crushed and fed to animals. It has a low cell wall component and is a rich source of protein (24.3%). Adult ruminant concentrate mixtures can include up to 50% of it. **Cull potatoes:** Ensiled potatoes, potato hash wastes (PHWs), undersized or oversized potatoes that do not match quality standards or grade, or that are damaged, can all be used as animal feed. The fresh cull potatoes are low in CP (9.5–10%) but high in starch (65–75%) and EE (0.4%). With a ME of 11.2 MJ/kg DM, PHW is a high-moisture (85%) by-product that comprises 70% starch, 10.5% CP, and 5.85% CF. In addition to their laxative qualities and digestive benefits, potatoes enhance flavor. Generally speaking, 1.0 kg of barley or maize grains is equal to 4.5–5.0 kg of potatoes. On a DM basis, these can make up as much as 30% of the animal diet.

**Empty pea pods:** Following pea shelling, empty pea pods (PP), which make up roughly 55% of intact pea pods and contain 19.8% CP and 1.0% EE, are the residue left over. They are abundant in macro- and micro-minerals, total phenolics (9.4%), and total soluble sugars (35.8%). Without compromising microbial biomass synthesis, metabolizable energy availability, volatile fatty acid generation, or nutrient utilization, empty pea pods could up to 50% of the total mixed ration be substituted for berseem hay.

**Tomato waste:** It contains tomato pomace (TP) and cull tomatoes. TP, which makes up 2–10% of processed tomatoes, is the mixture of skin, core, and seeds that remains after the pulp is extracted from the tomato processing industry. TP can either be fed fresh or preserved by ensiling or sun-drying. However, it cannot be ensiled on its own due to its high moisture content. As a result, it is advised to combine with 70:30 maize stovers or wheat/rice straw before ensile. 11–13% ether extract and 19–22% crude protein are present in TP. As a well-known antioxidant and a good supply of lycopene, a pigment that gives meat its color, TP may aid ruminants that are under oxidative stress. Without causing any negative effects, the sun-dried, ground TP could be used in place of 50–100% concentrate mixture or 40–50% of the buffaloes' entire meal. The potential for methane production from TP is far lower than that of traditional cakes.

**Cauliflower, cabbage and radish leaves:** These are very high in moisture (86–90%) yet have a CP content of 17–20%. In all of these VWs, albumin made up the largest percentage of the protein fractions, followed by glutelins, globulins, and prolamins. Ca, P, Na, K, S, Zn, Mn, Mo, and Co are all abundant in the majority of VWs. Some businesspeople have created equipment that can be used to use agricultural waste, including soybean haulms, wheat and paddy straw, and other horticulture waste. After being steam sterilized, agricultural waste is shred and mixed with ground horticulture waste in equal amounts to create pellets that can be used as animal feed.

**Sarson Saag (mustard leaves) waste:** The leaves of Brassica campestris (mustard), Spinacea oleracea (spinach), and Trigonella foenum-graecum (fenugreek) are steam-cooked in a 95:4:1 ratio to make Sarson Saag, an Indian delicacy. The cut leaves are cleaned thoroughly and then steam-cooked. After being sieved, the pulp is prepared for human consumption. The remainder of the fibrous component is referred to as "Sarson Saag waste (SSW)." It is disposed of on waste land, endangering the ecology. SSW is a good source of water-soluble sugars (6%), and it has 14.5% CP. It has been determined that SSW supplemented with a mineral mixture is very palatable, can be fed as a complete feed, and is a great source of nutrients for ruminants. 50–55 kilograms of fresh SSW can be consumed by adult buffaloes in a single day.

1. **Nutritive Properties of FWs**

According to Conrad and Blackstone (2019), the daily nutritional value of FW or loss is roughly 1200–1500 food calories. According to Brennan and Browne2021, between 30 to 60% of FWs are composed of carbohydrates, 5 to 10% of proteins, and 10 to 40% of fats. According to Schanes et al. (2018), the following categories account for the generation of FW, expressed in grams per person per day: cooked food (56%), vegetables (18%), fruits (16%), dairy (3%), and cereals (4%). Food waste from animals is generally a valuable source of nutrients. As a result, it might be utilized as a substitute for animals as an energy source.As a result, it might be utilized as a substitute for animals as an energy source. To supply an animal's protein needs, one tonne of dry FW is believed to be equivalent to the same quantity of maize grain (Wu et al 2015). The primary feed source, maize, which contains 8–10% protein, can be substituted with FW (Esteban and Ladero, 2018). Recently, insects have been utilized to compost organic waste. Because they are more nutrient-dense than other foods, they are also used as animal feed.The value of the black soldier fly Hermetiaillucens as animal feed is demonstrated by the fact that its mature larvae contain 40–45% protein in biomass and up to 35% fat by dry weight (Miranda et al., 2019).Peel, pomace, and seeds from food waste have twice as much bioactive compounds and polyphenols as the edible ingredient used to make animal feed. In vertebrates, the compounds in FW have anti-bacterial, anti-oxidative, anti-cancer, and immune-stimulating qualities. They are also associated with a decreased risk of cardiovascular disease (Wadhwa and Bakshi 2013).Carotenoids from tomato peel and carrot pomace, anthocyanin from banana bracts, and betalains from beetroot pulp are among the dyes found in FW. By inhibiting lipid peroxidation in animals, these colors' antioxidant qualities can be employed to shield living things from oxidative damage and increase the stability of food (Wadhwa and Bakshi 2013).

**4. Strategies for converting FWs for animal Feed**

Wet, dry, and ensiling/fermenting processes are the three main approaches for treating food waste that have been identified. Wet-based systems use a basic heating stage to produce feed that has a moisture level of 70–80%. Wet-based feeds required less preparation time than dry-based feeds. However, if they are not refrigerated, they will only last a few days. Typically, animals at the feed-producing plant unit are fed wet-based feeds rather than being transported across large distances. Dry-based methods involve drying food waste till the moisture content is less than 20%. Because of their low moisture content, dry feeds have a longer shelf life and a smaller bulk volume than wet feeds, which makes them easier to handle and less costly to transport and store.

Animal feed can be made from spoiled tiny bananas, banana peels, apple pomace (the leftover material after the fruit's juice is extracted), and vegetables such fresh potatoes and pineapple crowns (Wadhwa and Bakshi, 2013).Table 3. lists the various waste categories and the kinds of animal feed that can be produced from them.Most importantly, materials can be recycled for animal feed or further processed to extract or manufacture various value-added commodities as an alternative to such disposal techniques.

 **Table 3:** Various food waste types and their utilization in animal feed

|  |  |  |  |
| --- | --- | --- | --- |
| **Type of waste** | **Constituents**  | **Animal Feed**  | **References**  |
| Apple Pomace | 7.9% crude protein 5% Ether1.86 ME\*/kg 1.06–1.12 ME\*/kg | Milking cow Boar  |  (Ajila et al., 2015) |
| Banana peels | 8% protein 6.2% Ether 4.8% phenolic 13.8% soluble sugars | Pigs Rabbi |  (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 200–1000mg/kg beta carotene | Laying hens Rabbits 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

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 foods are examples of toxic waste from fruits and vegetables. Food waste is highly fermentable and prone to deterioration because of its high moisture content (80–90%), total soluble sugar concentration (64%), and crude protein level (10–30%). The development of suitable conservation techniques is necessary to ensure that these resources can be provided to cattle all year round, especially during the off-season for the production of green fodder (Wadhwa and Bakshi, 2013).

**5. Food waste in poultry feeding**

One of the essential part of livestock is poultry. The flesh of chickens is highly sought after in most parts of the world due to its robustness and rapid maturity. It is predicted that meat production will rise 66% globally and 78% in industrialized countries by 2050 (Mottet and Tempio 2017). Energy, crude protein, and crude fiber must all be balanced in broiler and layer diets.An animal's feed conversion ratio may be increased by a well-balanced diet that takes into account both the animal's nutritional needs and the nutrient makeup of the feed ingredients. Numerous studies have shown that chickens fed food waste—which includes trash from different food segments at varying percentages—performed similarly to maize and soy when compared to a traditional diet of maize and soy. The manufacturing and processing industry produces meat meal, cornﬂake leftovers, carrot top hay, and dried tomato pomace. Broiler feed has been successfully formulated from bakery trash.Truong et al. (Truong et al. 2019) found that adding dried bakery items up to 10% did not significantly alter the body weights or feed conversion ratios of 56-day-old broilers fed just corn/soy. When compared to 42-day-old broilers fed solely maize or soy, Siddiqui et al. (Siddiqui et al., 2021) also found that adding up to 30% dried bakery waste did not significantly change body weight, feed conversion ratio, or feed intake.

**6. Safety Regulations**

Disease-causing bacteria may be present in untreated FW. It was illustrated by the foot-and-mouth disease outbreak that occurred in the UK in 2001 and was brought on by pigs being fed leftover food. The use of FW in animal feed was outlawed by the UK government at the same time, and the European Union followed suit subsequently. FWs that don't contain any meat, fish, or other animal products are exempt from this ban (Mallinson et al., 2016). Since recovered feeds may contain potentially hazardous bacteria and/or viruses, proper heat treatments can render them safe for use by cattle. For the sake of FW safety, these wastes should be heated for more than 30 minutes to a temperature over 70°C.

**7. Conclusions and Future Perspectives**

Because it contains a high concentration of nutrients, FW can have major environmental repercussions if not disposed of or managed appropriately. Water pollution, acidification, eutrophication, and greenhouse gas emissions are a few examples of this. One practical way to mitigate environmental harm is to turn these food wastes into beneficial animal feed. Although it is common practice to feed livestock, leftovers from human meals, certified quality feed production and scientifically approved production methods are necessary for wholesome livestock development in all areas. For the safe and practical conversion of FW into a variety of dry and liquid animal feeds, several technologies have been developed. Turning FW into animal feed is one way that can open pathway to the creation of a circular economy as well as the accomplishment of sustainable development. In future, incorporating inexpensive foods produced from FW into animal diets will eventually offer the chance to lower the cost of animal rearing.

**Future Perspectives**

* Reducing food loss is a key strategy to increase food security at the national and international levels. It also helps to improve the management of land, water, and energy resources in food production systems, which is necessary to meet the United Nations' (UN) 2030 goal of halving the amount of food waste that occurs at the retail and consumer levels worldwide and reducing food waste along supply chains and production.
* Collecting and distributing consumer food waste efficiently and cost-effectively is a big concern, typically leading to disposal in landfills or water bodies as the most economically viable option. Furthermore, transporting waste commodities across great distances presents logistical issues. As a result, an organized method is required for food waste and use throughout the food supply chain.
* Comprehensive machine learning-enabled data analytic tools may help analyse the compounding data on waste to gain a deeper understanding of where, how, and why waste happens, as well as greatly optimize the supply chain process of various food items.
* Diverting food loss and waste to livestock and poultry feed could be a sensible way to limit the use of landfills and water bodies as an environmentally friendly disposal technique.
* In India, broad use of food waste as animal feed will require consumer and business cooperation, policy changes, and investment in collection infrastructure.
* Food waste is generated by food manufacturers, cafeterias, households, and food markets. While some food waste can be fed directly to livestock farms, others need to be processed to separate the edible part from the foreign and inedible ones. The waste fraction that is unsuitable for feeding could be composted or bio digested.
* The diversity of by-products and food waste impose challenges as their nutrient composition may vary significantly within and between lots, making it difficult to balance diets to meet animal requirements.Diets must be checked for quality, supplemented with nutrients that are lacking, and pelleted before feeding in order to improve the nutrient balance of wastes used as feed for livestock and poultry.
* Because of the high moisture content of most food waste, it must be used right away or undergo further treatment (such ensiling) to keep large amounts of fruit and vegetable waste from spoiling.
* Creating business plans and appropriate financing programs around the nation to help MSME sector decentralized processing units use waste from different industries, such as meat, fish, horticulture, and food.
* Centres will be established in every state to provide a sufficient supply of microbial culture to small units for the profitable conversion of more than 20% of food industry waste.
* Utilizing and popularizing established technology from institutions is necessary to turn food wastes from different industries into resources for fish and livestock feed.

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