**Waste to Wealth –Use of Food Waste as Animal Feed and beyond**

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**ABSTRACT**

Food waste is a matter naturally linked with the growing challenges of food security, resource and environmental sustainability, and climate change. In develop countries the largest food waste occurs in the consumption stage at the end of the food chain. Current approaches for dealing with the wasted food have serious restrictions. Historically, livestock animals had functioned as bio-processors, turning human-inedible or -undesirable food materials into meat, eggs, and milk. Contemporary treatment technologies can help convert the food waste into safe, nutritional, and value- added feed products. Recovering consumption- stage food waste for feeding to animal is a feasible result that contemporaneously addresses the issues of waste management, food security, resource conservation, pollution and climate- change mitigation.

1. **INTRODUCTION**

Livestock production is a pivotal component of agricultural growth in India. The growing unborn demand for livestock products driven by increases in income, population and urbanization will impose a massive demand on feed resources. Coincidently, the sustainability of feed production systems is under stress due to depletion of natural resources like land, soil and water, food-fuel-feed competition, global warming and inconsistent climate change. This imposes growing demand for arable land for non-agricultural purposes. Thus any strategy for sustainable livestock development require to revolve around efficient use of available feed resources including reduction in food wastage, and build out of alternate feed resource without competing with human food. With adding population of Indian livestock, there is a shortfall of about 35.0, 30.0 and 48.0 per cent of dry fodder, green fodder, and concentrates, respectively. It is expected by the year 2030; over 100 million tonnes of waste that is generated annually from fresh and processed fruits, vegetables, dairy, fish, poultry and meat sectors is not being gainfully recycled as animal feed. Moreover, a large proportion of these wastes are dumped in landfill/rivers which causes environmental hazards. By 2050, it is estimated that 68 % of the world’s population will live in urban areas, leaving only 30 of the population to produce the vast amounts of fruits, vegetables, and livestock products needed by urban residers (Elechi et al. 2022).

Reduction of food loss and waste is a serious challenge in India, which needs to feed its rapidly growing population (1.7 billion by 2050) (Murillo-Roos et al 2022)**.** Three times as much food is wasted as is produced each year (or 1.3billiontonnes) (Koul et al 2022)**.** Farmers can enhance their earnings by utilizing food scraps to lower the cost of animal feed. Another crucial advantage is the reduction of environmental difficulties caused by the decomposition of such wastes. Therefore, a feasible strategy is an absolute necessity to reclaim and efficiently 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 WASTES FROM DIFFERENT SECTORS**

Food waste (FW) is described as the wastage in amount food that occurs at the end of the food chain. This loss of food results in a forfeiture of resources such as water, labour, energy, and land that were used in production cycle, which also losses for retailers and consumer (Ishangulyyev et al 2019). Different estimates claim, 69 million metric tons (Mmt) of fresh waste is generated from various food sectors, including 50 kg food waste/capita/year, in addition to about 500 Mmt of farm waste. It offers a great compass to develop value addition in animal feeds and supplements. Moreover, with increase in processing of cereals, pulses, oilseeds, fruit and vegetables for value added food products for human consumption, more by-products/waste are likely to be generated. In India, the total availability of such food waste is more than 30 Mmt tonnes (FAO, 2019). India stands second in the world in the production of fruits and vegetables (FAO, 2019). A gradual move in the cropping pattern from cereals to lucrative fruits and other horticultural crops result in generation of huge quantity of fruit and vegetable wastes. Most of these are either composted or dumped in landfills which further adding to the environmental pollution. But such un conventional resources can be used as an excellent source of nutrients for farm livestock. Slaughtering of animals produce only 30% meat yield of the total weight, while the rest goes as by-products and wastes. These wastes like trimmings, inedible fat, blood, feathers, ruminal content, bones, egg shells etc. are generally used for producing pet foods, livestock feeds, pharmaceuticals, fertilizer or biogas. Further, these waste materials are normally converted into intermediate products like meat cum bone meal (MBM) or di-calcium phosphate (DCP), which are then mixed with various feed ingredients as feed supplements for fish, poultry, and pets like dogs and cats. Therefore, there is a huge potential for establishing by-products and waste utilization facilities in animal feed production.Table 1 enlists different industries involved in food waste along with the percentage of food waste amount they generate. The generation of food waste/capita country wise are presented in Table 2.

**Table 1** Estimation of waste in different food sectors (Hasan and Muneera 2022)

|  |  |  |
| --- | --- | --- |
| **SN** | **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 |

**Table2.** Country and households’ food waste.

|  |  |  |  |
| --- | --- | --- | --- |
| Country Food | Study Area | 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) |

**3. Types of FWs used as Animal Feeds**

**3.1 Processed Food Wastes**

The limitations in utilizing food wastes include (i) the acidic nature of various foods (ii) existence of spices and condiments (masala), which slow down the growth of the food grade organisms and enhance proliferation of spoilage organisms, (iii) combination of a wide variety of food material like fried, baked, steamed and raw and their variable combinations, leading to difficulties in standardization of feed stock (iv) difficulty in balancing of solid to liquid ratio and (v) deficiency in nitrogen content. Lactic acid bacteria (LAB) are ideal for treating the food wastes for feeding of both poultry and other farm animal. Low, medium, or high populations of LAB, as needed can be used in the feed. In urban hotel, marriage and other events feeding large numbers of people where there is a matter of serious concern for disposal of food waste without polluting the environment. As per one case study in Bangalore, more than 940 tonnes of food are wasted per during marriage functions. With proper planning and execution, it is possible to recycle a portion of the edible parts of such food waste for feeding hunger people, and the remaining can be used for other purposes such as in animal diets, pharmaceuticals, cosmetics, fertilizers/compost, as well as biodiesel or natural gas production through anaerobic digestion. Using the food waste, it is also possible to farm the insects like black soldier flies and further use protein rich insects as the feed for poultry birds and fish. Moreover, there is also a chance of utilizing this wastage in food packaging industry by using the expired packaged food materials for insect farming. Presently, there is no regulation to check this wastage. Responsible food waste management and disposal policy is demanded for various segments of food processing industry.

**3.2 Dairy Waste**

The fast-growing dairy industry produces over 1.2 million tons of residues (whey, ghee, butter serum) annually. The challenges for using these as animal feed include economic feasibility, collection and distribution logistics, feed safety and regular assessment of nutrient quality. Some strategies that can be employed are heat sterilization, drying and ensiling with or without addition of fermentation aides like bacteria and enzymes. Use of these by-products from dairy industries can lower the feeding cost of the livestock. Skim milk and butter milk once considered as by-products of the industry are now regarded as value added products and marketed at the price of milk. The by-products, produced in large quantities which not utilized appropriately are whey, ghee residue, buttermilk produced during churning of butter and butter serum during pre-stratification of ghee manufacture. The skimmed milk powder waste can be efficiently utilized in monogastric animals and calf diets. Whey is generated in large amount during cheese, paneer and chhana production. Roughly, 8 litres of whey is produced for every 10 litres of milk used for the production of cheese, paneer and cottage cheese (chhana). Whey has about 6% solids (half of what is contained in milk) and some of the constituents such as whey proteins possess high nutritive value. Technologies have been developed to use this by- product for the making of whey protein concentrates and whey powder If whey is used for manufacturing of beverages and bakery products, it not only saves water required for their production but also adds nutritive value to such products. Further, India imports lactose, a major constituent of whey. This also gives scope for utilization of whey for lactose production, thereby reducing its import. Ghee residue is a good source of nutrients and antioxidants. Its brown colour and nutty flavour makes it highly suitable as an ingredient for the preparation of baked foods such as cookies and biscuits. A simple intervention can help to make value-added nutritive food products from it. Buttermilk produced during churning of butter as well as butter serum produced during the pre-stratification method of ghee preparation usually goes waste, while it could be effectively blended with curd and used for making buttermilk and lassi.

**3.3 Vegetable Waste**

India produced over 197 million tons of vegetables in 2020-21. The production will continue to increase in the future, making available various vegetable by-products and wastes amounting to about 32 million tons for use as animal feed. Following are some of the major items which account for the bulk of these: Baby corn by-products: Baby corn is eaten both raw and cooked. In India, the average production of baby corn is about 7.5–8.7 tonnes/ha. The production of by-products/wastes from baby corn is: husk and silk (5.56 tonnes/ha), stalks and leaves after harvesting ears (30 tonnes/ha) and masculine buds (3.13 tonnes/ha) (FAO, 2019; Mani et al. 2019; Bhattacharjya et al. 2019). These by-products/wastes can be fed fresh or after ensiling, and have comparable/better nutritive value than maize fodder. Besides selling baby corn cob for human consumption, farmers can get additional income by selling baby corn fodder from baby corn plant.

**Bottle gourd pulp:** The residue after extraction of juice is called bottle gourd pulp. It is also a good source of bio-active components like 2,2-diphenyl-1picryl-hydrazyl-hydrate (DPPH), vitamin C, flavonoids and total phenolics. It can be preserved after sun-drying and then ground for feeding to animals. It is a good source of protein (24.3%) and has a low cell wall constituent. It can be incorporated up to 50% in the concentrate mixture of adult ruminants.

**Carrot by-products:** These include cull carrots, carrot tops and carrot pomace after extraction of juice. Cull carrots are more palatable and readily consumed by cattle. Fresh carrot contains 10% crude protein (CP), 1.4% ether extract (EE) and up to 60% sugars, mostly sucrose on dry matter basis, which make carrots both highly digestible and palatable. Carrot is a rich source of vitamin C and carotene. Carrot may bea staple diet of horses.

**Empty pea pods:** After shelling peas, the leftover material is empty pea pods (PP) constituting about 55% of intact pea pods, which contain 19.8% CP and 1.0% EE. These are rich in total soluble sugars (35.8%), total phenolics (9.4%) and macro- and micro-minerals. Empty pea pods could replace berseem hay in total mixed ration up to 50% level without affecting nutrient utilization, volatile fatty acid production, metabolizable energy availability and microbial biomass production.

**Cull potatoes:** The under or over-sized potatoes, which do not meet the quality standards or grade, or are damaged, potato waste from cold storages, ensiled potatoes and potato hash wastes (PHWs) have wide applications as animal feed. The fresh cull potatoes contain 65–75% starch and 0.4% EE, but are low in CP (9.5–10%). PHW is a high-moisture (85%) by-product which contains 70% starch, 10.5% CP and 5.85% CF with ME of 11.2 MJ/kg DM. Potatoes improve the palatability, have laxative properties, and are good for digestion. As per the general recommendation, 4.5–5.0 kg potatoes are equivalent to 1.0 kg barley or corn grains. These can be incorporated in the animal feed up to 30% on DM basis.

**Sarson Saag (mustard leaves) waste:** Sarson Saag (an Indian dish) is prepared by steam-cooking leaves of Brassica campestris (mustard), Spinaceaoleracea (spinach) and Trigonella foenum-graecum (fenugreek) in a 95:4:1 ratio. After thorough washing, the chopped leaves are steam-cooked. The pulp is sieved and processed for human consumption. The leftover fibrous fraction is a waste, called ‘Sarson Saag waste (SSW)’. It is dumped on the waste land posing a threat to the environment. SSW contains 14.5% CP and is a good source of water-soluble sugars (6%). It is concluded that SSW supplemented with mineral mixture is highly palatable, can serve as an excellent source of nutrients for ruminants and can be fed as a complete feed. Adult buffaloes can consume 50–55 kg fresh SSW in a day.

**Tomato waste:** It includes cull tomato and tomato pomace (TP). The mixture of skin, core and seeds left after the extraction of pulp from tomato processing industry is called TP, which constitutes 2-10% of processed tomatoes. TP can be fed fresh or preserved either by sun-drying or by ensiling. However, due to high moisture content, it cannot be ensiled alone. Therefore, it is recommended to mix with wheat/rice straw or maize stovers in 70:30 and then ensile. TP contains 19–22% crude protein and 11–13% ether extract. TP is a good source of lycopene, a pigment that gives colour to meat and is a known antioxidant, which may help in relieving oxidative stress in ruminants. The sun-dried, ground TP could replace 50-100% concentrate mixture or 40-50% complete diet of buffaloes without any adverse effect. TP has significantly low methane production potential as compared to conventional cakes.

**Cauliflower, cabbage and radish leaves:** These contain 17 to 20% CP, but have very high moisture content (86-90%). Among protein fractions albumin constituted the major proportion followed by glutelins, globulins and prolamins in all these VWs. Most of the VWs are good sources of Ca, P, Na, K, S, Zn, Mn, Mo and Co. Some entrepreneurs have developed machinery suitable for utilization of horticultural waste along with the agriculture waste, such as paddy and wheat straw, soybean haulms etc. Agricultural waste are shredded and added to the ground horticultural waste in equal proportions and pellets are prepared for using as animal feed after steam sterilization.

**3.4 Fruit Wastes**

India produced over 103 Mmt of fruits in 2020-21. Currently, commercial processing of fruits is extremely low at around 2.2% of the total production. Being perishable, over 60 million tons of waste from fresh fruits and vegetables is generated annually. Challenges in converting horticultural byproducts to feed include aggregation and segregation, perishability, seasonality, logistics, admixture with plastic as well as the waste from domestic sector. The engineering interventions for processing include mechanized ensiling, cost effective energy efficient processes of moisture removal and densification, and efficient anaerobic fermentation of the biomass. Some examples of major fruit wastes are discussed below.

Citrus waste: The citrus pulp contains 60–65% peel, 30–35% internal tissues and up to 10% seeds. Due to the high moisture and sugar contents, and presence of mould and yeast, citrus pulp gets rapidly deteriorated and may cause environmental pollution. Thus, it must be sun dried and pelleted to increase density or to be ensiled. It contains 5–10% crude protein and 6.2% ether extract, 10–40% soluble fibre (pectins), 54% water-soluble sugars and trace elements. Dried citrus pulp is used as a cereal substitute in concentrate diets because of its high organic matter digestibility (85-90%) and energy availability for lactating dairy cows. Dried citrus pulp can replace 20% concentrate in lactating dairy cattle. Kinnow mandarin (Citrus reticulata) waste (KW) constituted 50% of processed kinnows. KW could replace barley grains in concentrate mixture up to 50% level without affecting nutrient utilization, VFA production, ME availability and microbial biomass production. Fresh KW was mixed with wheat straw (WS) in 75:25 ratios and ensiled for 42 days in tube silo. The feeding of KW-WS silage based TMR did not show any adverse effect on blood profile, purine derivatives excreted in urine and N-retention in buffalo calves.

Pineapple waste: The post-harvest processing of pineapple fruits yields crowns, peels, cores, fresh trimmings and the pomace as pineapple waste, which account for approximately 30–35% of the fresh fruit weight. Another waste product is the pineapple bran, which is the solid residue obtained after pressing macerated skins and crowns. The wet bran can be fed fresh to animals or ensiled. Pineapple waste contains 4–8% crude protein, 60–72% fiber, 40-75% soluble sugars as well as pectin, but it is relatively poor in minerals. Pineapple waste can be mixed with hay, wilted grass or rice straw and then ensiled. A 75-day field trial on lambs offered total mixed ration (TMR) containing either maize or pineapple waste silage along with concentrate mixture in 62:38 proportion revealed comparable nutrients utilization, serum biochemical and mineral profiles and performance in both the groups (Gowda et al. 2015). Another 90-day feeding trial revealed significant increase in milk yield of crossbred cow fed TMR in which the green fodder was replaced with ensiled pineapple waste. Ensiling of pineapple waste not only reduced the cost of feeding but also helped in overcoming the disposal problem.

The use of fruits and vegetables waste (FVWs) in animal diet can reduce the cost of animal feed and increase livestock farmers’ income. Furthermore, these unconventional feed resources are good alternative to maize and possibly other feed constituents that compete with human food, thus minimizing the food–feed competition. Some of the FVWs are excellent sources of antioxidants, pigments like carotenoids, lycopene, poly-phenolic compounds, pectins, anti-carcinogenic compounds, essential oils, as well as bioenzymes viz., α-amylase, hemicellulase and cellulase, lignin and manganese peroxidase and laccase etc. Some of the major constraints in the utilization of FVWs are the presence of heavy metals, pesticide and their residues,alkaloids, mycotoxins and anti-nutritional factors. Presence of these agents at high levels in the diet can adversely impact animal health and welfare. These toxic agents can get transferred to animal products, which may affect human health. Regular monitoring and testing of the potential toxic agents is advocated before the FVWs are used in animal feeds.

**3.5 Wastes from Aqua Sector**

Indian fish production during 2020-21 is estimated to be about 15 million tons. Fish processing and domestic fish markets generate 30 to 55% of materials as waste. Average waste generation in India is 3 million tons, which is equivalent to 21% of the total fish production. Fish wastes contain valuable nutrients like proteins, lipids, minerals and vitamins. Hence, aquatic waste is a potential source for production of several useful molecules such as chitin, collagen, keratin, PUFA, and proteolytic, chitinolytic and collagenolytic enzymes as well as amino and carboxy peptidases. The lack of baseline data on availability and quality of aqua waste, scattered nature of domestic market for fish waste, poor quality raw material, lack of cold chain facilities, dearth of indigenous processing plants of desired quality standards, poor industry-research institution partnership and lack of appropriate policies are some of the major challenges impacting the secondary fish processing. There are opportunities to promote secondary fish processing to produce high value and specialty compounds as well as industrial and formulated products. The Central Institute for Fisheries Technology (ICAR-CIFT), Cochin has developed several technologies including edible value added products (battered/ breaded products, pickle & soup) from fish waste, protein based products (meal, protein concentrate, hydrolysates, fish peptone, functional peptides, collagen peptide, collagen concentrate &gelatin), lipid based products (body oil, liver oil, PUFA concentrate), minerals (fish bone calcium) and specialty products like chitin, chitosan, chitin derivatives, hydroxyapatite, astaxanthine and squalene.

For accomplishing proper processing of fish waste, following measures are needed:

* Conducting Nationwide Awareness campaigns on waste utilization.
* Building a national database on availability of secondary raw aquatic material at various hot spots.
* Identification of potential technologies available with various institutes like CIFT for establishing technology demonstration centers, and scaling up of such technologies for handling aqua waste to produce high value products.
* Separate government supported schemes to back above activities.

**3.6 Wastes from Meat Processing**

Appropriate waste disposal system from the meat processing centers is important in preventing environment pollution and spread of diseases. Presently, the solid waste from the slaughterhouses is collected and dumped in landfills or open areas, while the liquid waste is sent to municipal sewerage system or water bodies, thus endangering public health as well as terrestrial and aquatic life. The chemical composition of slaughter house waste water is similar to that of the municipal sewage with 45% soluble and 55% suspended organic composition. Blood has a very high chemical oxygen demand of around 375,000 mg/L and is one of the major dissolved pollutants in slaughterhouse wastewater. In most of the developing countries, there is no organized strategy for disposal of solid and liquid wastes generated in abattoirs. By-products from the animal slaughter constitute about 50% of the live weight, and their utilization and value addition may ensure better returns to the stakeholders. Animal by-products, particularly blood, is considered as liquid meat as it contains good amount of protein (~ 17%) and has a perfect amino acid balance. Porselvam and Srinivasan (2017) observed that anaerobic co-digestion was feasible and offers a viable treatment technology for utilizingwastes from the meat processing. Karthik et al (2010) studied the composition and storage stability of poultry feed, and observed that dry rendering is a safe method for destruction of microbes in the raw material and preparing good quality pet food for dogs by incorporating spent hen meal.

**4. Nutritive Attributes of FWs**

The nutritional value of FW or loss per day has been estimated to be approximately 1200–1500 food calories (Conrad and Blackstone 2019). Carbohydrates make up around 30 to 60% of FWs, whereas proteins range from 5 to 10%, and fats make up 10 to 40% (Brennan and Browne). The generation of FW, measured in grams per person per day, can be broken down into the following categories: cooked food (56%), vegetables (18%), fruits (16%), dairy (3%), and cereals (4%) (Schanes et al 2018). Mostlyanimal food waste is a good source of nutrients. Therefore, it can be used as an alternative source of energy to animals. It is thought that1 tonne of dry FW could be used instead of the same amount of maize grain to meet an animal’s protein needs (Wu et al 2015). FW can be used instead of maize, which is a main feed source and has 8 to 10 percent protein (Esteban and Ladero, 2018). Recently, organic waste is being composted with the help of insects which are also being used as animal food because they are more nutritious than other foods. The fact that a mature larva of the black soldier ﬂy *Hermetiaillucens* has 40 to 45% protein in biomass and up to 35 percent fat by dry weight demonstrates its usefulness as animal feed (Miranda, et al 2019).The concentration of bioactive chemicals and poly phenols in food waste peel, pomace, and seeds is double that of the edible component used in animal feed production. The chemicals found in FW have anti-cancer, anti-bacterial, anti-oxidative, and immune-stimulant properties in vertebrates, as well as being linked to a lower prevalence of cardiovascular disease (Wadhwa and Bakshi 2013).FW has dyes such as carotenoids from tomato peel and carrot pomace, anthocyanin from banana bracts, and betalains from beetroot pulp. These dyes have anti-oxidant properties that can be used to protect living organism from oxidative damage and making foods more stable by preventing lipid per oxidation in animals (Wadhwa and Bakshi 2013).

**5. Methods of Converting FWs into Animal Feed**

There are major three food waste treatments technologies that have been identified i.e. wet, dry and ensiling/fermenting procedures. A simple heating stage is involved in wet-based systems, which provide feed with 70–80 per cent moisture content. In comparison to dry-based feeding, wet-based feeds required less preparation time. However, they can only last a few days if not refrigerated. Wet-based feeds are normally not transported for long distances but instead fed to animals in the feed-producing plants unit. Dry-based approaches entail drying food waste to a less than 20% moisture percentage. Dry feeds have a long shelf life and a small bulk volume compared to wet feeds due to their low moisture content, making them more manageable and less expensive to store and transport. The spoiledsmall-sized bananas, banana peels, apple pomace (the residue remaining after the juice being 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.3presents different types of waste and the types of animal feed that can be made out of it.Above all an alternative to such disposal methods, materials can be recycled for animal feed or further processed to extract or manufacture various value-added items.

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Type of waste** | **Constituents** | **Animal Feed** | **References** |
| Apple Pomace | 7.9% crude protein  5% Ether  1.86 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

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. 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. Food waste in poultry feeding**

Poultry is an important component of livestock. Chickens meat is high demand in the majority of the world’s regions because they are robust animals and mature very quickly. By 2050, it is anticipated that worldwide meat production willincrease by 66% and that of industrialized nations will increase by 78% (Mottet and Tempio 2017).In broiler and layer diets, it is crucial to maintain a balance of nutrients including energy, crude protein, and crude ﬁbre. A well balanced diet based on the nutritional demand of the animal and nutrient composition of the feed ingredients may stimulate the animals’ feed conversion ratio. According to various studies, when compared with a conventional maize and soy diet, chicken fed food waste consisting of trash from various foods segments at different percentages performed similar to maize and soya. 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) discovered that 56-day-old broilers fed only corn/soy had no signiﬁcant variations in body weights or feed conversion ratios when dried bakery goods up to 10% was added. Additionally, Siddiqui et al. (Siddiqui et al 2021) discovered that when compared with 42-day-old broilers fed only corn/soy, the addition of up to 30% dried bakery waste did not signiﬁcantly alter body weight, feed conversionratio, or feedintake.

**7. Safety Policies**

Untreated FW may contain pathogens that cause disease. It was demonstrated by that with the outbreak of foot-and-mouth disease in the United Kingdom, around 2001, which was due to feeding uncooked food waste to pigs. In the same time, the United Kingdom government banned the use of FW in animal feeding, and later, on the European Union issued a similar prohibition. This prohibition does not apply to FWs that contain no meat, ﬁsh or other animal products (Mallinson et al 2016). Appropriate heat treatments can make recovered feeds safe for livestock feeding by removing potentially harmful bacteria and/or viruses that may be present in these types of feeds. A prolong heating of these waste to temperature above 70◦C for more than 30 min in order to ensure safety of FW.

**8. Conclusions and Future Perspectives**

Due to the fact that it includes a lot of nutrients, FW can have serious consequences on environment if it is not properly disposed of or handled. This includes but is not limited to, greenhouse gas emissions, eutrophication, water pollution and acidiﬁcation. Converting these food scraps into useful animal feed is a feasible solution that can help reduce environmental damage. Though it is normal practice to use leftovers from human meals to feed livestock, scientiﬁcally authorized production methods and certiﬁed quality feed production are essential for healthy livestock production in all regions. Different technologies have been developed for the safe and viable conversion of FW into various dry and liquid livestock feeds. 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 the future the incorporation of low-cost FW-derived items into animal diets will, provide the opportunity to reduce rearing cost of animals.

**Future Perspectives**

* Minimizing food loss is an important approach to improve national/global food security and it further improve management of land, water, and energy resources in food production systems to meet the United Nations (UN) 2030 goal to halve per capita global food waste at the retail and consumer levels, and reduce food wastage along both production and supply chains.
* Efficient and cost-effective collection and distribution of consumer food waste is a major challenge, with disposal in landfills and water bodies often deemed as the most economically viable option. Further, transportation of waste commodities over long distances creates logistical challenges. Therefore, an organized approach is essential to food waste accounting and utilization along the food supply chain.
* Comprehensive ML-enabled data analytic platforms can help understand the compounding data on waste to get a clearer picture of where, how, and why waste occurs and contribute significantly to improve supply chain process of various food items.
* Diverting food loss and waste towards livestock and poultry feed could emerge as a rational solution to reduce use of landfills and water bodies as an environment friendly strategy for disposal.
* The widespread use of food waste as animal feed in India will require consumer and industry support, policy change and investment in food waste collection infrastructure.
* Food waste arises from food processors, cafeteria, households, and food markets. Some food waste can go directly to livestock farms as feed, whereas others require feed processing to separate usable food waste from inedible and foreign contaminants. The waste portion which is unsuitable for feeding could be directed toward composting or bio-digestion.
* 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. To improve nutrient balance wastes as livestock and poultry feeds, diets need to be monitored for the quality and added with deficient nutrients and pelleted prior to feeding.
* High moisture content of majority of food wastes, necessitates immediate use or further treatment (e.g., ensiling) to prevent spoilage of huge quantities of fruit and vegetable wastes.
* Designing suitable financial schemes and business models in different parts of the country to support the decentralized processing units in MSME sector to utilize waste from various sectors like food/fish/horticulture/meat etc.
* Establishment of hubs in each state to ensure adequate supply of microbial culture to the small units for profitable conversion of over 20% waste produced from the food industry.
* Utilization and popularization of proven technologies from Institutes is required for conversion of waste from various sectors into feed resources for the fish and livestock.

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