POLICY PAPER 115

Waste to Wealth – Use of Food Waste as Animal Feed and Beyond

NATIONAL ACADEMY OF AGRICULTURAL SCIENCES, NEW DELHI
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Preface

Food waste produced across the supply chain and its subsequent disposal pose serious environmental, social, and economic consequences. FAO (2019) has defined food waste using two indices: food lost in production or in the supply chain before it reaches the retail (*Food Loss Index*) or food that is subsequently wasted by consumers or retailers (*Food Waste Index*). As per UNEP Food Waste Report, 2021, 931 million tonnes of food is wasted annually by households, retail establishments and the food services industry. India generates about 100 million tons (Mmt) of fresh food wastes and 500 Mmt of farm wastes every year, which are valued roughly at INR100,000 million per year due to lack of focus on finding an upcycling solution to realize their gainful utilization. Addressing the stupendous task of getting rid of food wastes and making them useful for other purposes requires setting up a supply chain to ensure optimized pickup of food surplus and rejects. Diverting food loss and waste toward livestock and poultry feed is one of the most plausible solutions to reduce use of landfills and water bodies as a strategy for disposal. Utilizing food waste in animal diets addresses waste management and food security, besides resource and environmental challenges. A huge amount of human-inedible food and fiber by-products are being converted into human-edible food like milk, meat, eggs etc, by our livestock, highlighting the importance of waste utilization as an ecosystem service associated with indigenous system of livestock production. India's animal feed industry is massive and poised to grow at a CAGR of 9.6% in the next five years. Improving the economic efficiency of recycling by-products and food waste from agriculture and livestock production could create demand for these products within the animal and fish feed industry. A systematic approach to food waste accounting is also essential to design efficient and effective policies that result in reduced food loss and waste along the food supply chain.

In order to pave the way for a coordinated approach, National Academy of Agricultural Sciences organized a strategy workshop on *Waste to Wealth – Use of Food Waste as Animal Feed and Beyond* on December 03, 2021 to seek input from various stakeholders representing feed industry, researchers and policy makers for effective utilization of food waste for livestock diets. I thank the Conveners Drs N.K.S. Gowda and K. Giridhar for taking this initiative, Dr Kusumakar Sharma and Dr A.K. Srivastava for reviewing the paper and to all the eminent participants for their valuable inputs. I also take this opportunity to thank Dr Pratap Singh Birthal and Dr Malavika Dadlani for their editorial support. I hope this document will be useful to the policymakers and other stakeholders.

November, 2022
New Delhi

(Trilochan Mohapatra)
President

Waste to Wealth – Use of Food Waste as Animal Feed and Beyond

1. INTRODUCTION

Livestock production is a crucial component of agricultural growth in India. The growing future demand for livestock products driven by increases in income, population and urbanization will impose a huge demand on feed resources. Concurrently, 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 coupled with growing demand for arable land for non-agricultural purposes. Therefore, any strategy for sustainable livestock development needs to revolve around efficient use of available feed resources including reduction in wastage, and enlargement of the feed resource base without competing with human food. With the increasing population of Indian livestock, a shortfall of about 35.0, 30.0 and 48.0 per cent of dry fodder, green fodder, and concentrates, respectively, is expected by the year 2030, whereas 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 recycled gainfully as livestock feed. Moreover, a large proportion of these wastes are dumped in landfills or rivers, causing environmental hazards. Therefore, a viable strategy is an absolute necessity to recycle and efficiently utilize the waste generated from various food sectors to economise on animal feed and also alleviate the environmental pollution associated with their conventional disposal.

2. REUSABLE FOOD WASTES FROM DIFFERENT SECTORS

Though the accurate data on total wastes generated from various segments of food sector are not available, as per different estimates, ~ 69 million metric tons (Mmt) of fresh waste is generated from food sectors, including 50 kg food waste per capita per year, in addition to about 500 Mmt of farm waste. According to an estimate, the annual loss of 0.92% in milk, 2.71% in meat, 4.58-15.88% in fruits and vegetables, and other food and farm sectors amounts close to INR 90,000 cr (RePlanet, the Times of India, 26 Feb, 2022). It offers a great scope to develop value added animal feeds and supplements. Additionally, 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. Presently in India, the total availability of such waste is more than 30 Mmt tonnes (FAO, 2019).

India ranks second in the world in the production of fruits and vegetables (FAO, 2019). A gradual shift in the cropping pattern from cereals to more remunerative fruits and other horticultural crops is expected to result in generation of huge quantity of fruit and vegetable wastes. Presently, most of these are either composted or dumped in landfills adding to the environmental pollution for want of efficient and cost-effective collection and distribution net work. But such non-conventional resources can be used as an excellent source of nutrients for farm livestock. While the merits of using horticultural wastes include low disposal cost and better nutritive value, their high moisture content, rapid spoilage and added transportation cost pose some major drawbacks. Slaughtering of animals produce a meat yield of only 30% of the total weight, whereas the rest goes as by-products and wastes. Wastes like trimmings, inedible fat, blood, feathers, ruminal content, bones, egg shells etc. are generally used for producing pet foods, animal feeds, pharmaceuticals, fertilizer or biogas. These waste materials are normally converted into intermediate products like meat cum bone meal (MBM) or dicalciumphosphate (DCP), which are then mixed with different feed ingredients as feed supplements for poultry, fish and pets like dogs and cats. Hence, there is a huge potential for establishing by-products and waste utilization facilities.

2.1 Processed Food Wastes

The constraints in utilizing food wastes include (i) the acidic nature of majority of the foods, (ii) presence of spices and condiments (masala), which inhibit the growth of the food grade organisms and promote proliferation of spoilage organisms, (iii) mixture of a wide variety like fried, baked, steamed and raw food material, and their variable combinations, leading to difficulties in standardization of feed stock, (iv) problem in balancing of solid to liquid ratio and (v) deficiency in nitrogen content. Lactic acid bacteria (LAB), versatile in their sugar and nitrogen requirements, are ideal for treating the food wastes for feed of both poultry and farm animals. Low, medium, or high populations of LAB, as required, can be used in the feed. In urban hotel system as well as other events feeding large numbers of people, there is a serious concern for disposal of food waste without polluting the environment. As per one case study in Bangaluru alone, more than 940 tonnes of food is wasted annually during marriage functions. With proper planning, it is possible to recycle a portion of the edible parts of such food waste for feeding people to address hunger, whereas the remaining can be used gainfully for other purposes such as in animal diets, pharmaceuticals, cosmetics, fertilizers/compost, as well as biodiesel or natural gas production through anaerobic digestion. By using the food waste, it is also possible to farm the insects like black soldier flies and use these protein rich insects as the feed for poultry birds and fish. Similarly, there is also a possibility of recycling the wastage in food packaging industry by using the expired packaged food materials for insect farming. Though, there is no accurate data on the extent of commercial food waste generated in India, packaged food sales in India during 2020 were 47 Mmt, and even at a conservative estimate of 2% loss, the wastage amounts to over 2,500 tons per day. Presently, there is no regulation to prevent this wastage. Responsible food waste management and disposal policy is needed for various segments of food processing industry.

2.2 Dairy Waste

The rapidly 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 viability, collection and distribution logistics, feed safety and regular assessment of nutrient quality. Some of the strategies that can be employed are heat sterilization, drying and ensiling with or without addition of fermentation aides like bacteria and enzymes. Usage of the 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 and not utilized appropriately are whey, ghee residue, buttermilk produced during churning of butter and butter serum produced during pre-stratification process of ghee manufacture. Skimmed milk powder waste can be used in monogastric animals and calf diets. Whey is generated in large quantities during cheese, paneer and chhana production. Approximately 8 litres of whey is produced for every 10 litres of milk utilized 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 utilize this by-product for the preparation 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.

2.3 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-1-picryl-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 rich source of protein (24.3%) and has a low concentration of cell wall constituents. 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 highly 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 is a 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), *Spinace aoleracea* (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. Because of the 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 were rich 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.

2.4 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. Therefore, it should be sun dried and pelleted to increase density or should 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 ratio 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.

2.5 Waste 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.

2.6 Waste 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 slaughterhouse waste water are 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 utilizing wastes 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.

FUTURE STRATEGIES AND ACTIONABLE POINTS

- Minimizing food loss is an important avenue to improve national/global food security and 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 losses along 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, restaurants, households, and food markets. Some food waste can go directly to livestock farms as feed, whereas others require secondary processing to separate usable food waste from inedible and foreign contaminants. The portion marked unsuitable for feeding could be directed toward composting or bio-digestion.
- The heterogeneity of by-products and food waste creates challenges as their nutrient composition may vary considerably within and between lots, making it difficult to balance diets to meet livestock requirements. To improve nutrient

consistency and quality of food wastes as livestock and poultry feeds, diets need to be monitored for the quality and blended 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 like CIFT, NDRI, NIANP, CFTRI etc., is required for conversion of waste from various sectors into feed resources for the fish and livestock.

POLICY RECOMMENDATIONS

- The incentives and tax benefits are to be provisioned by the government to the MSME units engaged in utilizing the waste to produce valuable products (eg. livestock feed from insect farming by upcycling of food waste).
- A single Ministry needs to be designated at the centre to plan, implement schemes and facilitate efficient utilization of food wastes by using appropriate technology and machinery in a cluster approach.

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Note: The designations and affiliations of the participants are as on the date of BSS.

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