Indian Journal of Animal Sciences **94** (5): 395–400, May 2024/Review Article
https://doi.org/10.56093/ijans.v94i5.136138

Jackfruit waste and peels: Potential as livestock feed

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Received: 8 May 2023; Accepted: 12 March 2024

ABSTRACT

Feed and fodder problems could be well-addressed regionally using the vegetable wastes. The vegetable wastes are highly perishable and are very prone to spoilage due to high moisture content. These wastes are dumped in open areas contributing to unhealthy/unhygienic surroundings. One of the unexplored vegetable by-products is Jackfruit waste on which least research has been conducted for its possibility to be included in livestock feed. Jackfruit consumption and processing leads to the generation of enormous amounts of non-edible wastes of peel, central axis, and edible by-products like seed and perianth. Jackfruit peel is a rich source of bioactive antioxidants like vitamin C and beta-carotene, which protect the body against free radicals and strengthen the immune system. It is also rich in various phytonutrients such as alkaloids, lignans, isoflavones, and saponins. Thermal drying, grinding and fermentation with fungi and bacteria have been found effective for the inclusion of Jackfruit waste/peel in livestock meal.

Keywords: Jackfruit, Livestock feed, Peel, Waste

The animal husbandry sector in India has been successful in consistently improving its contribution to the agricultural sector over the last five years and has emerged as the most important sub-sector of agriculture. As per the Economic Survey (2021), Animal Husbandry contributes to support 4.20% of the national GDP and 28.63% of the total GDP from Agriculture and allied sectors. The number is realized as livestock rearing has always been an integral part of Indian agriculture and livelihood of people. The share of India's livestock population is the highest in the world, certainly leading to greater demand for livestock feed. However, the long-term insufficiency of feed and fodder has been the key constraint in achieving the production potential at par with the livestock population. The deficit is projected to rise further, valuing to 65% and 25.6% for green and dry fodder, respectively, by year 2025 (Sharma *et al.* 2012, 2013). ICAR-NIANP (2013) in its Vision 2050 has predicted shortage of 21.3% crop residues, 40% greens, and 38.1% concentrates by the year 2025. Owing to the shortage, feed cost accounts for the highest expense (70-75%) in livestock-rearing practices. Researchers are constantly working to exploit the potential of various by-products as livestock feed resources (Kour *et al*. 2022). Large amounts of by-products from agro-industries like oil cakes, brans, dried distillers' grain soluble, chunies, etc. are widely recognized for their nutritive potential and are common in use, so their cost has also increased substantially over time (Sharma *et al.* 2016, Swain *et al.* 2016). In the current situation, efforts to explore underutilized non-conventional feed resources and strengthen their nutritional quality would be economically worthwhile, since conventional feedstuffs are often expensive (Prusty *et al.* 2019, Singh *et al.* 2021). In this context, vegetable wastes seem to have escaped the due consideration it seeks for its inclusion in livestock feed, possibly due to its highly perishable nature. But, area-specific feeding problems could be well-addressed if in some way those could be included in livestock feeding practices.

Vegetable/ fruit by-products

Due to increasing demands for horticultural produce, there is an ongoing shift in the cropping pattern from cereals to more remunerative fruit and vegetable crops, which has resulted in increased production of vegetable and fruit by-products and wastes. A lot of waste in the form of whole fruit, peels, seeds, etc. is generated daily from fruit production to the processing chain. United Nations Food and Agriculture Organization (FAO) has estimated that at least one-third of the food produced in the world (estimated as 1.3 billion metric tonnes) is lost and wasted every year (Gustavsson *et al.* 2011) and losses and waste of horticultural commodities are the highest among all types of foods, reaching up to 60% (Sagar *et al.* 2018, Doneria *et al.* 2022, Prusty *et al.* 2023). Apples generate 10.91% of seed and pulp as by-products, and 89.09% of

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final product during slicing. Dicing papaya produces about 8.5% of peel waste, 6.5% of seeds, 32% of unusable pulp (because of imperfection in cubes), and about 53% of the final product. Pineapple processing yields about 14% of peels, 9% of core, 15% of pulp, 15% of top, and 48% of total final product. Processing of mangoes produces about 11% of peels, 13.5% of seeds, 18% of inoperable pulp, and 58% of finished products. Pomegranate peel is about 60% of fruit weight (Lansky and Newman 2007). About 500 g/kg of the total fruit weight corresponds to the peel, while the rest are the edible parts of pomegranate, consisting of 400 g/kg arils and 100 g/kg seeds. These wastes dumped in open areas, are very prone to spoilage due to high moisture content, thus they contribute to unhealthy/unhygienic surroundings. Fruits and vegetable waste generated after processing, packing, distribution, and consumption in the organized sector in India is about 1.81 million tonnes (Wadhwa and Bakshi 2013). Inventiveness for their use in livestock feed would help in preserving their nutrient value and decrease the cost of livestock production besides minimizing pollution hazards (Wadhwa and Bakshi 2013). The generated waste is rich in nutrient components such as carbohydrates, proteins, and vitamins depending upon on the sources. The isolated or extracted valuables from these wastes are evidently contributing to meet the nutritional requirements for humans, animals, and plants as well as in the pharmaceutical industry (Sogi *et al.* 2002, Singh *et al.* 2021, Singh *et al.* 2022).

Jackfruit: Potential of jackfruit waste as livestock feed

Jackfruit is a vegetable cultivated in tropical and sub-tropical countries like India, Sri Lanka, Bangladesh, Burma, Philippines, Indonesia, Thailand, Malaysia and Brazil. Its origin is believed to be the rainforests of the Western Ghats (Goswami *et al*. 2011). Even though widely grown, it is one of the underutilised vegetable by-products in the livestock feed (Ajey 2013). In India, the entire area under jackfruit farming is thought to be roughly 26,000 hectares, of which, an approximately 100,000 trees are grown-up in backyards and as an intercrop between other trade crops in South India. The topmost states growing jackfruit trees are mainly Kerala, Assam, West Bengal, Chhattisgarh, Madhya Pradesh, Tamil Nadu, Tripura and Karnataka (Arun *et al.* 2020). It is the largest tree borne fruit in the world with an average weight ranging from 2.10-10.22 kg (Mitra and Mani 1998) reaching up to 50 kg in weight. Up to 700 fruits weighing 0.5 to 50 kg are produced per annum from a tree. On average, 50-80 tonnes of fruits can be harvested from a hectare of land and India is the second biggest producer of the fruit in the world (Sidhu 2012). As per report of NHB (2018), Jackfruit production has grown from 1694,000 to 1830,000 MT from year 2016-17 to 2018-19.

Jackfruit consumption and processing leads to generation of high amount of non-edible wastes of peel, central axis, and edible by-products like seed and perianth. However, a limited number of research has been devoted for the investigation of possibilities for conversion of these wastes into value-added products. Hence, a significant amount of jackfruit waste is discarded creating serious waste disposal and environmental problems (Moorthy *et al.* 2017). Jackfruit peels, cores, and seeds left as waste during consumption as well as processing are reported to be a rich source of pectin, fibre, and starch.

Perianth meal, rind and core meal constitute a non-edible portion of the fruit and represent 59·2% of whole fruit with a total dry meal recovery of 11·6% (Subburamu *et al.* 1992). Central axis or core has been reported to have 20.5% carbohydrate, 10.6% crude protein, and 15.9% crude fibre (Subburamu *et al*. 1992). About 30% of the fruit weight is occupied by the flesh (Ranasinghe *et al.* 2019) and nearly 70% of the jackfruit which consist of aerial part, skin, seed and heart is discarded after the fleshy parts are taken out (Kusmartono 2002). During peak production season, whole fruits are also available as a farm waste. A comparative analysis of different wastes obtained from jackfruit is provided in Table 1. A study on by-products of fruits and vegetables including Jackfruit revealed higher levels of minerals in the by-products rather than in the pulps of fruits (Chiocchetti *et al.* 2013).

Silage prepared from jackfruit had 96% OM, 8.3% CP, 1.7% EE, 38.1% NDIN (Neutral detergent insoluble nitrogen), 15.9% ADIN (Acid detergent insoluble nitrogen) and 69.8% NFC (Non-fibrous carbohydrate). Jackfruit waste collected from vegetable market had OM content of 92.01% (Dutt *et al.* 2008). DM and OM digestibility of 72.15% and 73.89%, respectively and ME of 9.56 MJ/kg

Table 1. Chemical composition of different jackfruit wastes (Nutrients g/100 g)

Nutrients (g/100 g)	Water	Crude protein	Crude fat	Total carbohydrate	Crude fibre/ NDF*	Reference
Young fruit	76.2-85.2	2.0-2.6	0.1-0.6	9.4-11.5	2.6-3.6	Swami *et al*. (2012)
Ripe fruit	72-94	1.2-1.9	0.1-0.4	16-25.4	1.0-1.5	
Seed	51-64.5	6.6-7.04	0.4-0.43	25.8-38.4	1-1.5	
Raw seed	-	15.1	0.983	-	4.2	Ndyomugyenyi (2016)
Peel	76.33	1.54	1.71	5.92	13.51	Koh *et al.* (2014)
Peel	80.23	6.52	7.47	-	20.50	Reyes *et al.* (2018)
Jackfruit waste from vegetable market	84.70	8.41	3.27	-	16.90	Dutt *et al*. (2008)
Unripen Jackfruit silage	35.05	9.52	2.07	-	36.11*	Suma *et al.* (2023)
Jackfruit residue silage	32.52	8.77	1.91	-	34.08*	Suma *et al.* (2023)

DM have been reported in Jackfruit waste (Bakshi *et al.* 2016). Solid-state fermentation of jackfruit waste by probiotic yeast and lactic acid bacteria is advantageous for livestock feeding. Fermentation of jackfruit waste with *S. boulardii* and lactic acid bacteria *L. acidophilus* demonstrated CP of 9.59% and 9.32%, respectively (Munishamanna *et al*. 2020). The increase in the protein content of jackfruit waste is possibly due to utilization of sugars and nitrogen sources by the probiotic yeast and *Lactobacillus acidophilus*.

Kusmartono (2002) demonstrated better acceptance of Jackfruit waste by sheep compared to cattle. Free access to jackfruit waste and rice straw revealed 92% of intake of the basal diet was in the form of jackfruit waste in sheep compared to 47% in cattle. But rumen NH_3 concentration (58.2 mg/L) was below optimum whereas addition of urea (3% of diet DM) depressed intake of jackfruit waste by sheep. Escala and Bestil (2014) studied the efficacy of jackfruit by-product (skin, pith and rugs) concentrate (JBC) for early weaning of suckling kids of 15 days and 30 days old. Feeding JBC @1% of BW on DM basis three times weekly caused significant increase in voluntary DMI, cumulative weight gain and ADG than daily supplementation. It also promoted attainment of normal rumen *p*H and higher bacterial population in rumen. ADG of 60 g, 90 g and 110 g were attained at 4th, 6th and 7th weeks on three times weekly feeding of JBC to 15-days age kids. Supplementing jackfruit wastes *ad lib.* to rice straw and urea molasses block resulted in daily body weight gain of 95.6 g per day in 2-2.5 years old sheep.

Azevedo *et al*. (2015) observed linear decrease in BW and average daily gain with the replacement of corn for jackfruit silage (0, 333, 666 and 1000 g/kg DM of corn) and inferred that jackfruit silage could replace corn in diets of lambs anywhere economic factor was crucial. Arun *et al.* (2020) observed that Jackfruit residue (rind and rag) silage (JRS) prepared from rind and rags of jackfruit along with 1% ground maize grain had higher CP (8.77 vs. 3.35%) and EE (1.91 vs. 0.79%) and lower total ash (6.46 vs. 8.51%), NDF (34.08 vs. 71.84%), ADF (27.88 vs. 46.46%) and ADL (1.06 vs. 3.83%) content as compared to the finger millet straw. They observed better ADG without significant (P>0.05) difference in total DM intake and nutrient digestibility, when finger millet straw was replaced at 25% and 50% level by JRS.

Replacing one third of concentrate feed with about 5 kg of fresh jackfruit waste in diet of crossbred lactating cattle resulted in a reduction in feed cost per kg milk production by 15% without altering feed consumption and milk yield. They estimated DCP of 4.17% and a high TDN of 72.6% in jackfruit waste. The *in vitro* DM, OM digestibility and ME of seeds were 82.6%, 84.6% and 10.88 MJ/kg DM, respectively (Bakshi *et al.* 2016). Eyoh and Udoh (2020) observed that when Jackfruit seed meal (JFSM) was incorporated at 5% level, the diet enhanced nutrient intake, digestibility and nitrogen utilization in goats (Table 2). Zuwariah *et al.* (2018) observed best essential amino acid composition in thermal processed jackfruit seed followed by germinated jackfruit seed and raw jackfruit seeds. Total ash, crude fat, carbohydrate and total fibre was lowest in whereas the CP content (24.94%) and energy value was the highest in thermal jackfruit seed flour. Highest vitamin C content (78.78 mg/100 g) was observed in germinated jackfruit seed flour.

Potential of jackfruit peel as livestock feed

Jackfruit is composed of three main regions- fruit axis, perianth and true fruit. Perianth is made up of bulb (edible region), middle fused region (rind) and non-edible region (spikes). Peel or rind or skin is the outer covering of fruit. It ranges from green to yellow-green colour depending upon its stage of maturity. The rind thickness enlarges from about 0.4 to 1-2 cm (Haq 2006) at maturity. Roughly, annual jackfruit peel manufacturing is estimated to be 2714 -11,800 kg per tree (Ramya *et al.* 2020). Jackfruit peeling machines are available to peel the outer rind of the fruit. The outer peel of jackfruit is rich in fibrous compounds, calcium, and pectin (Moorthy *et al.* 2017), and constitutes about 59% of the ripe fruit. Moisture and ash content of Jack fruit peel was reported in range 4.8-10% and 2-4%, respectively (Soetardji *et al.* 2014). Chemical composition of jackfruit peel compared to other fruits and vegetable peels is provided in Table 3.

The use of processed Jackfruit peel in confectionaries

Table 2. Jackfruit waste utilization in livestock

Treatment	Production	Reference
Straw diet supplemented with Jackfruit waste and cassava leaves at 3%	BW gain and DM digestibility was improved in growing sheep when Jack fruit waste was supplemented with cassava leaves (112 g/day) as protein source compared to other nitrogen sources like molasses urea block (97.1 g/day).	Kusmartono (2007)
Supplementation of Jackfruit (*Artocarpus heterophyllus*) residue silage with straw based diet replacing 50% of finger millet straw	Average daily gain was higher in lambs. There was no significant difference in feed conversion ratio and nutrient digestibility.	Arun *et al.* (2020)
Inclusion of processed (raw or soaked of toasted) Jackfruit seed meal at 5% level in diet	Nutrient intake, digestibility and nitrogen utilization was increased in West African dwarf goats.	Eyoh and Udoh (2020)
Jackfruit by-product concentrate supplemented to Napier grass feeding	Supplementation of jackfruit by-product concentrate three times weekly significantly increased voluntary dry matter intake of Napier grass and weight gain of suckling kids.	Escala and Bestil (2014)

Table 3. Comparative nutrient composition of Jackfruit peel with other vegetable and fruit peels

Particular	Moisture	Total ash	Crude fat	Crude protein	Crude fibre	Carbohydrate	NDF	ADF
Pomegranate peel	-	6.07	3.36	3.46	17.63	59.98	20.8	15.1
Watermelon peel	92.6	5.03-10.2	1.8-12.61	10.2-12.42	26.31-39.1	32.16	33.8	33.7
Papaya peel	86.8	11.6	2.2	20.2	16.5	-	13.04	18.61
Orange peel	78.32	5.17-6.75	5.64-8.70	7.53-9.73	14.19-24.65	53.27	62.17	32.00
Pineapple peel	82.7	4.39-5.0	1.1-5.31	5.11-8.8	14.80-16.3	55.52	25.01	18.88
Mango peel	72.01	2.34-3.24	0.42-4.72	5.0-9.12	5.24-15.43	63.80	35.12	10.13
Apple peel		1.39	4.72	2.80	13.95	59.96		
Banana peel	89.8	12.45-12.8	5.5-8.40	9.7-10.44	11.81-24.2	43.40	35.8	25.3
Jack fruit rind flour	10.83	6.28	0.78	4.25	10.10	77.86	-	-

Source: Bakshi and Wadhwa (2013), Okoruwa and Igen (2014), Romelle *et al.* 2016, Morais *et al.* 2017, Ramya *et al.* 2020, Wimalasiri *et al*. 2021, Jalal *et al*. 2023.

and human foods broadens the hope of its suitability for inclusion in livestock feed (Feili *et al*. 2013, Ramya *et al.* 2020). As per Zhang *et al.* (2017), the peel extract exhibited the highest total phenolic content that was 4.95, 4.12 and 4.65 times higher than the seed extract, flake, and pulp of Jackfruit, respectively. Jackfruit peel extract also exhibited the highest DPPH and ABTS+ scavenging ability. The three most abundant phenolics derived from jackfruit peels were gallic acid, chlorogenic acid, and catechin. Polyphenol content of jackfruit rind was higher than the fruit peels of pineapple, pomegranate, and orange, which contributes to its antioxidant action (Meera *et al*. 2018). Antioxidant property of jackfruit owes to the presence of a phenolic acid known as caffeic acid (Magnani *et al.* 2014). Caffeic acid has been reported to have antibacterial properties *in vitro* and it could possibly prevent cardiovascular diseases (Magnani *et al*. 2014). Jackfruit possesses anti-inflammatory, antibacterial, antifungal, antidiabetic, anthelminthic, antihypertensive and antiaging properties and is reported to be rich in B complex, viz. vitamin B_6, riboflavin, niacin and folic acid (Goswami *et al.* 2011). Jackfruit is assumed to have anticancer and antiaging properties due to presence of lignans, isoflavones and saponins. (Lee *et al.* 2013). Phytochemicals in jackfruit to possess antiviral, antimalarial and anti-inflammatory properties (Wei *et al.* 2005). Phenolic compounds (artocarpesin, norartocarpetin and oxyresveratrol) extracted from jackfruit were reported to have strong anti-inflammatory properties.

Sundarraj and Ranganathan (2017) found jackfruit peel to be rich in cellulose, (27.75%), pectin (7.52%), protein (6.27%) and starch (4%) whereas the mineral contents were reported as calcium, 30.445 ppm; iron, 4.184 ppm; manganese,1.873 ppm; copper, 0.735 ppm and zinc, 0.9982 ppm. With the hypothesis of improving the cellulosic waste products rich in nutrients through solid stage fermentation, Reyes *et al.* (2018) studied the effect of *Aspergillus niger*, *Rhizopus stolonifer*, *Rhizomucor pusillus* and *Aspergillus fumigatus* isolated from vermicast on the proximate composition of jackfruit peel and found *R. stolonifer* suitable for enriching the proximate composition of jackfruit peel. To explore the possibility of utilizing jackfruit peel waste as protein supplement, solid state fermentation with *Saccharomyces cerevisiae* (5% for 72 h at 40°C) resulted in 17.1% protein (Sousa *et al.* 2020). Mashudi and Nurmavati (2022) observed improved Dry Matter Digestibility (DMD) and Oragnic Matter Digestibility (OMD) with increased proportion of jackfruit peel in rumen liquor (50%, 60%, 70% and 80%) and the digestibility was improved on adding *Aspergillus oryzae* at 0.4% level. Arun (2021) observed no adverse effect on nutrient utilization, milk composition, haematology, and serum biochemical profile of Osmanabadi goats.

Conclusion

Jackfruit peel is an underutilized waste generated from vegetable market on which least research has been done. Because of its nutritional value in terms of minerals, vitamins, carbohydrate and total phenols attributing to antioxidative property, it could be well-explored as a feed for ruminants. Positive outcome from scarce *in vitro* and *in vivo* studies, hold promise for inclusion of jackfruit peels in ruminant feed. Thus, more research should be undertaken for its successful inclusion in livestock ration for reducing the feed cost and bridging the feed deficit gap in jackfruit grown areas.

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