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Review Article

Food Processing Unit By-products and its Use in Animal Nutrition

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Introduction:

By 2050 the world will need to feed an additional 2 billion people and require 70 % more meat and milk. The increasing future demand for livestock products, driven by increases in income, population and urbanization will impose a huge demand on feed resources. Sustainability of feed production systems is being challenged due to biophysical factors such as land, soil and water scarcity, food-fuel-feed competition, ongoing global warming and frequent and drastic climatic changes, along with increased competition for cultivated land and non-renewable resources such as fossil carbon-sources, water and phosphorus. A key to sustainable livestock development is efficient use of available feed resources including reduction in wastage, and enlargement of the feed resource base through a quest for novel feed resources, particularly those not competing with human food (Kishan P. Patel & Shrikant B. Katole, 2023).

A huge quantity of fruit and vegetable wastes (FVW) and by-products from the fruit and vegetable processing industry are available throughout the world. For example fruit and vegetable processing, packing, distribution and consumption in the organized sector in India, the Philippines, China and the United States of America generate a total of approximately 55 million tonnes of FVW. A large proportion of these wastes are dumped in landfills or rivers, causing environmental hazards. Alternatives to such disposal methods could be recycling through livestock as feed resources and/or further processing to extract or develop value-added products.

Currently, livestock is one of the fastest growing agricultural subsectors in developing countries. The demand for livestock products is rapidly increasing in most developing countries. However, many developing countries have feed deficits. New unconventional alternate feed resources could play an important role in meeting this deficit. Fruit and vegetable processing, packing, distribution and consumption generate a huge quantity of fruit and vegetable wastes, for example, approximately 1.81, 6.53, 32.0 and 15.0 million tonnes of fruit and vegetable wastes are generated in India, the Philippines, China and the United States of America, respectively and most of this is being disposed of either by composting or dumping in the landfills/rivers, causing environmental pollution. Such unconventional resources can act as an excellent source of nutrients and help to bridge the gap between demand and supply of feedstuffs for livestock. In addition, their use can also reduce the cost of feeding, giving higher profits to farmers. In India a shortage of 25, 159 and 117 million tonnes of concentrates, green forages and crop residues, constituting respectively a shortage of 32, 20 and 25 % of the requirement has been estimated (Gorti *et al.*, 2012). Under these conditions, to meet the nutrient requirements of livestock and to sustain their productivity and profitability seem only possible if non-conventional, alternate feed resources are explored. Further alternate feed resources would be more effectively utilized by imparting certain feed processing and treatments like soaking, toasting and chemical treatments for minimizing the anti-nutritional factors with fibrolytic enzymes and natural growth promoter's supplementation which can improve overall digestibility of fibrous fodder and performance of animals (Patel K. P. *et al.,* 2020; Kishan P. Patel & Shrikant B. Katole, 2023)

Constructive use of naturally occurring top crops can be used as livestock feed due to their rich nutrient content, making the usage of herbal plants advantageous for livestock, poultry, and swine husbandry which had conclusively demonstrated that, by-product of feed processing unit might be helpful in fighting against antimicrobial resistance and use as livestock feed (Parmar *et al.* 2022). It is time to take action against antibiotic resistance. There is substantial evidence of antibiotic residue in bovine milk and resistant bacteria in cattle, according to pioneering studies (Patel *et al.*, 2019; Patel *et al.*, 2020). Research have demonstrated that antimicrobial-resistant bacteria are being acquired by infants at a young age (Tumlam *et al.*, 2022). Phytogenic chemical and herbal plants have been demonstrated to ameliorate fatty liver disease and possess antiviral properties (Parmar *et al.*, 2022; Ghoke *et al.*, 2018).

Industrialization of food production has resulted in a generation of large quantities of food waste that can be classified into the following six categories: (a) crop waste and residues; (b) fruit and vegetables by-products; (c) sugar, starch and confectionary industry by-products; (d) oil industry by-products; (e) grain and legume by-products; and (f) distilleries and breweries by-products. Fruit and vegetable processing by-/co-products are promising sources of valuable substances such as phytochemicals (carotenoids, phenolics, and flavonoids), antioxidants, antimicrobials, vitamins, or dietary fats that possess favorable technological activities or nutritional properties. These fruit and vegetables remnants are less digestible due to presence of lignocellulosic bonds, high levels of silica and anti-nutritional factors which not only reduces the production potential but also affects the profitability of farmers. Use of enzymes, probiotics, prebiotics and nutraceuticals (Patel K. P. *et al.*, 2020; Patel *et al.*, 2018) are found to be effective in such conditions.

The three main parameters affecting the application of alternative feed ingredients in animal nutrition are related to animal factors and the presence of anti-nutritional factors, production logistics and profit that is extended from the food processing industry to the feed industry and, finally, to the farmer. The same factors affect the application of fruit and vegetable co-products in livestock nutrition.

Factors affecting the application of fruit and vegetable co-products in animal nutrition

- Seasonal and/or local supply
- Adequate product quantity as raw material to support a supply chain
- Collection, transportation and processing cost
- Limited knowledge of processing, storage and handling conditions
- Unknown effects on nutrient digestibility related to processing conditions and/or different feed formulations (matrices)
- Product biosecurity and safety

- Feed palatability and animal response to the diet
- Variable product composition
- Unknown production costs
- Limited or no knowledge of inclusion levels—Application of "best guess" theory for feed formulation
- Anti-nutritional factors

Requirements for application of fruit and vegetable co-products in animal nutrition

- Product standardization and precise description
- Nutritional valuation
- Product compliance with legislation
- Product handling and storage
- Knowledge of the action mode
- Active compounds and bioavailability
- Knowledge of the presence of anti-nutritional factors
- Low cost

Apple *(Malus domestica)*

The residue left after extraction of the juice, called apple pomace, could be used as a livestock feed. The dried apple pomace contains 7.7% crude protein (CP) and 5.0% ether extract (EE). It has 1.86 M cal metabolizable energy (ME)/kg DM and 1.06–1.12 Mcal net energy (NE)/kg DM for lactating dairy cows. (Ghoreishi *et al.*, 2007). Incorporation of up-to 30 % ensiled apple pomace in the diet of lactating multiparous Holstein cows, did not show any adverse effects on milk yield or its composition. However, the best feed conversion ratio was observed at 15 % incorporation in the diet.

1 Apple pomace

The dried apple pomace can be used as an energy source in broiler rations replacing maize by 10% (w/w), without adversely affecting the broiler production. Incorporation at >10 % leads to production of wet litter and depresses feed efficiency, mainly due to higher fibre content. Better performance of broilers fed on apple pomace diets supplemented with a commercial enzyme preparation (α-amylase, hemicellulase, protease and β-glucanase) compared with those that were not supplemented(Matoo, Beat, Banday, & Ganaie, 2001).

Banana *(Musa acuminata)*

About 30–40 % of the total banana production is rejected for failing to meet quality standards and is potentially available for feeding to livestock. Banana wastes include small-sized, damaged bananas, banana peels, leaves, young stalks and pseudo stems, which can be fed to livestock. Fresh plantain and banana fruits may be ensiled with molasses, grass, legumes, rice bran etc. Green fruits are easier to ensile than ripe fruits. Whole, fresh banana leaves, stalks and pseudo stems are chopped and directly fed either fresh, sun-dried or ensiled with molasses in many tropical countries. Pseudo stems are easily ensiled if chopped and mixed with molasses or rice bran.

Leaves, young stalks and pseudo stems

Banana leaves contain about 15% DM and 10–17% CP, while pseudo stems contain 5–8% DM and 3–5% CP. The NDF and ADF vary between 50–70% and 30–40%, respectively. Banana leaves contain 8% polyphenols, but very few condensed tannins and also shows low feacal egg counts of hemonchus controtus in lambs which suggests that it may also have fecundity on adult parasites (Marie-Magdeleine *et al.*, 2010). The organic matter (OM) digestibility of pseudo stems is higher than that of leaves mainly because the erectness of pseudo stems is primarily due to the presence of water in the cells, and not because of the presence of lignin in the cell wall (Ffoulkes & Preston, 1978).

Ruminants - Banana leaf meal (leaves chopped and sundried) up to 40% in the forage based ration on DM basis increased weight gains and feed efficiency of Zebu cattle and sheep (García *et al.,* 1973) and Fresh banana foliage up to 15% (El-Ghani, 1999); dried foliage ensiled with dried broiler litter in a 40:60 ratio and rehydrated with either molasses or whey included at 15% (Khattab *et al.,* 2000), foliage and wheat straw (75:25) ensiled with molasses and urea (Baloch *et al.,* 1988) could replace 50 % of green maize in the rations of lactating cows/buffaloes without altering milk production.


2 Banana leaves and stalk

Non-Ruminants - Banana leaf meal could be used up to 15% in the diet of growing pigs, resulting in satisfactory average daily gain and feed conversion efficiency. Rabbits can be fed up to 40% banana leaves without adverse effects on growth, feed intake and digestibility (Rohilla & Bujarbaruah, 2000). And in poultry it can be used up-to 10%.

Banana peels

Banana peel constitutes about 30% of fresh banana by weight. These can be fed to livestock as fresh green, ripe or dried. Ripe banana peels contain up to 8% CP and 6.2% EE, 13.8%, soluble sugars and 4.8% total phenolics. Banana peels are rich in trace elements, but Fe, Cu and Zn contents are much higher than the maximum tolerance limit for ruminants, suggesting that these should not be fed *ad libitum*, but should be supplemented in the ration of ruminants as source of organic minerals. Green peels have approximately 15% starch which gets converted to sugars as the fruit ripens and the ripened peel has approximately 30% free sugars. Tannins mostly present in the peels are responsible for the astringent taste of immature fruits, which adversely affect their palatability in monogastric animals, while there is no palatability problem with peels of the mature/ripened fruit. Ripening causes migration of tannins to the pulp or they get degraded by polyphenol oxidases and peroxidases.

Ruminants - Banana peels are widely used by small, marginal and landless farmers as complementary feeds for ruminants in the tropics. Dairy cows fed 14–21 kg of fresh ripe banana peels increased milk production (Dormond *et al.,* 1998) while In goats, dry ripe plantain peels can replace up to 100% maize without adversely affecting grow performance, and were found to be an economical source of carbohydrates (Aregheore, 1998).

Non-ruminants - Sun dried ripe plantain peels could replace 75–100% of maize in weaned rabbit diets with positive economic returns. Inclusion rates beyond 30% in diet adversely affected daily weight gain and feed conversion efficiency (Fanimo & Odu, 2006). Dried banana peels incorporated up to 10% in broiler diets improved the live weight gain and feed conversion efficiency. However, inclusion beyond 10% in the diet depressed the growth. An equal mixture of banana peels and golden snail (*Pomacea canaliculata*) meat could replace up to 90% of a commercial diet for ducks (Letty June & Santos, 1995).

Citrus pulp

The residue left after extraction of the juice is called citrus pulp (50–70% of the fruit by weight). It contains 60–65% peel, 30–35% internal tissues and up to 10% seeds. Adult crossbred cattle can consume 50–60 kg fresh citrus pulp daily. But it is perishable due to the presence of high contents of water so it should be sun dried and pelleted to increase density or should be ensiled. While drying, lime is added to neutralize the free acids, bind the fruit pectins and release water. It contains 5–10% CP and 6.2% EE, 10–40% soluble fibre (pectins) and 54% water soluble sugars, 1–2% calcium due to the addition of lime and 0.1% phosphorus. The composition of dried citrus pulp is variable and depends mainly on the relative proportions of skins and seeds, which varies according to the citrus species, variety and the harvesting season.

3 Citrus plup

Ruminants - Dried citrus pulp is used as a cereal substitute in concentrate diets due to its high OM digestibility (85–90%) and energy availability. Unlike, cereals its energy is not based on starch but on soluble carbohydrates and digestible fibre. Citrus pectins are easily and extensively degraded, producing acetic acid, which is less likely than lactic acid to cause a pH drop and result in acidosis. Due to its high fibre content, the long rumination of citrus pulp produces large quantities of saliva that has a buffering effect on rumen pH. Citrus pulp is therefore considered as a safer feed than cereals for animals fed high-concentrate, low-roughagevdiets as in high-yielding dairy cows.

Dried citrus pulp can replace 20% concentrate in dairy cattle (Assis *et al.*, 2004) and up to 30% in lactating ewes (Fegeros *et al.,* 1995) without adversely affecting DM intake, rumen metabolites, digestibility, milk yield or milk protein and fat contents. A silage mixture containing 70% fresh citrus pulp had no adverse effect on milk yield or composition, but increased fat content (6.85% vs. 5.85%) when offered to primiparous dairy ewes in late lactation (Volanis *et al.,* 2006).

Non ruminants - Dried citrus pulp may be included up to 20% and 15% in the diets of pregnant and lactating sows respectively, without affecting reproductive and productive performance (O'sullivan *et al.,* 2003). (Sotto *et al.*, 2009) used citrus pulp up to 50% in the diets of gestating and lactating sows without deleterious effects on performances and productive indices. Dried citrus pulp can be incorporated in diets of rabbit at 20–30% levels (Hon *et al.*, 2009). The level of citrus pulp in the diets of poultry should not exceed 5–10% because of the presence of non-starch polysaccharides which impaired growth rates, lowered feed efficiency and reduced carcass yields (Mourão *et al.*, 2008). Citrus pulp silage can be included at 5–10% in the diet of growing pigs, which reduced the feeding cost. Pigs offered citrus pulp showed significantly lower *Enterobacteria* counts in faeces compared with pigs in the control group. However, no difference was observed in the *Lactobacilli* count (Cerisuelo *et al.*, 2010).

Mango *(Mangifera indica L.)*

The edible pulp makes up 33–85% of the fresh fruit, while the peel and the kernel amount to 7–24% and 9–40% respectively, on a fresh weight basis. The by-products/ wastes available after processing of mango includes cull fruits (fresh fruits unsuitable for human consumption), mango kernel meal (containing 6–16% mango oil on DM basis), deoiled mango kernel meal and mango peels.

Mango seed kernel have anti-nutritional factors like tannins, which progressively lead to depression in growth rates and efficiency of feed utilization, when included as a major component in diets of pigs and poultry. They also contain 64 mg/kg DM cyanogenic glucosides, 42 mg/kg DM oxalates and 20 TIU (trypsin inhibiting unit)/g DM trypsin inhibitors. Amongst the different treatments, soaking in water was most effective, and it removed 61% of the tannins and 84% of hydrocyanic acid (HCN).

4 Mango seed kernal

Mango seed kernels

Ruminants - Mango seed kernels can be incorporated in the concentrate mixture up-to 50% without any adverse effects and in sheep up-to 70%.

Non ruminants - Raw mango seed kernel meal included at 5–10% in the diet depressed feed intake and growth in broiler chicks (El Alaily *et al.*, 1976). Optimum growth is to use boiled mango seed kernels <5 % in broiler chicks during the starter phase (0–28 days) and 10–20% in the diets of broilers during the finisher phase (28–63 days) on DM basis (Diarra & Usman, 2008; Joseph & Abolaji, 1997). (Odunsi, 2005) stated that 5% raw mango seed kernel meal in layers decreased laying rate and increased weight loss in layers.

Mango peels

Ruminants - Mango peels can be fed fresh, dried or ensiled. Due to the high Sugar content (13.2% they are palatable and considered as an energy feed, but the high moisture and acidity of fresh peels may limit their use in ruminants. Because of their low protein content, addition of a source of nitrogen or protein is necessary to allow efficient utilization of the energy in the diet. In order to produce good silage, mango peels were mixed with rice straw and legume to facilitate fermentation.

5 Mango peels

Non ruminants - Dried mango peels up to 10% in the diet of finishing pigs had no deleterious effect on feed conversion ratio or performance and economized feeding cost (Rao *et al.*, 2003).

Pineapple *(Ananas comosus)*

The post-harvest processing of pineapple fruits yields skins, crowns, and waste from fresh trimmings and the pomace after extracting the juice. Fresh pineapple cannery waste can be preserved either by drying or ensiling. Pineapple bran is the solid residue of the pressed macerated skins and crowns. It can be fed either fresh, ensiled or after drying to the animals. Raw pineapple waste (on DM basis) contains 4–8% CP, 60–72% NDF, 40–75% soluble sugars (70% sucrose, 20% glucose and 10% fructose) as well as pectin, but it is poor in minerals. Therefore, it should be supplemented with protein and minerals in order to prevent detrimental effects on productivity and health.

Ruminants - Pineapple wastes are highly palatable and digestible (73–75% OM digestibility) in cattle, sheep and goats. Ensiled pineapple waste fed to steers up to 70% of the diet with a protein supplement and 2.5 kg fresh forage resulted in high daily weight gains (1 kg/day) and also decreased the cost of feeding (Geoffroy *et al.*, 1984) It could also replace up to 60% of maize silage without affecting daily weight gains (Prado *et al.*, 2003).

Baby corn *(Zea mays Linn)*

Only 15% is the edible baby corn cob, while 85% is constituted by outer peels with a silky thread like structure called baby corn husk which is a waste material and is a source of environmental pollution. A number of other by-products are tassels and green plant material. The wastes/by-products, if used judiciously, can give additional income to the farmers.


6 Baby corn ensiling in bag

Fresh baby corn husk (BCH) contained 11.7% CP and 1.8% EE. Fresh chaffed BCH, or BCH wilted for 2–3 days and ensiled for 42 days or fresh BCH mixed with chaffed rice straw in a 70:30 ratio (BCH-RS) and ensiled for 42 days can be feeded to animals. The higher digestibility of nutrient, N-retention, apparent biological valve and favourable rumen environment conclusively revealed that fresh or ensiled BCH was highly acceptable and palatable, comparable with conventional maize fodder.

After taking 3–4 baby corn picks, the left over plant was harvested to be used as fodder for livestock. It contained 92.2% OM, 11.7% CP, 59.2% NDF, 30.4% ADF, 28.8% hemicelluloses and 37.1% cellulose. The chemical composition was quite comparable with that of the conventional maize fodder. The studies on male buffalo calves revealed that ensiled baby corn fodder and ensiled maize fodder in complete feed had comparable DM intake, digestibility of nutrients and N-retention in male buffalo calves (Bakshi *et al.*, 2013).

Carrot *(Daucus carota)*

Feed carrots are usually cull (grade-out) or surplus carrots obtained during glut season of production. These can be fed fresh (whole/chopped), ensiled or dehydrated. Other carrot products that occasionally are fed to livestock include the carrot tops and carrot pomace after extraction of juice. Fresh carrot contains 10% CP, 1.4% EE, up to 60% sugars, mostly sucrose (on DM basis). A rich source of vitamin C (300–700 mg/kg DM) and carotene, depending on the carrot variety; orange carrots contain 200–1000mg/kg DM of β-carotene.

Ruminants - Fresh carrots can be fed up to 20 and 25 kg/day to young bulls and dairy cows and can be included up to 40% in the diet of steers, without any adverse effects (Rust & Buskirk, 2008). Preventing acidosis and scouring, and should be introduced progressively in the diet (8–10 days). Prolonged use of carrots in the diet of dairy cows increased the carotene content of the milk and produced yellow colored milk fat. A significant improvement in the reproductive performance of high-yielding cows fed 10 kg/day fresh carrots in the diet was observed; a decrease in the calving interval from 167–185 days to 110–171 days, a decrease in the number of inseminations necessary for successful fertilization (1.8–2.7 to 1.0–1.8) and an increase in the calving rate (84.5 to 92 %). The milk yield and fat content were not affected (Car, 1985).

Non-ruminants - Carrot is a staple diet of horses. Dehydrated carrots and carrot flakes are common commercial treats for horses. Fresh carrots are used in low amounts (2–3 kg/day) for working horses, and these are mostly used to maintain appetite and facilitate the consumption of dry feeds. Carrots can provide carotenoids to laying hens. The yolk colour of the egg was improved significantly when 4–8% dried carrot meal was used in the diet of laying hens compared with a wheat-based control diet. Body weight gain, egg production and feed conversion were not affected (Sikder *et al.*, 1998). Giving egg-laying hens access to maize silage, barley-pea silage and carrots as forage materials decreased pecking behaviour, thus improving animal welfare (Steenfeldt *et al.*, 2007).

Carrot tops

Carrot tops contain 11–12% CP, 17% crude fibre and up to 18% ash due to residual dirt. Carrot top hay replacing 50% of berseem hay in the diet of Rahmani sheep increased nutrient digestibility (Bassiouni *et al.*, 1999). Carrot tops fed at 5% to laying hens improved s-carotene content of egg yolk and did not affect egg weight, Haugh unit, egg-shape index and strength and thickness of the eggshell (ISHIKAWA *et al.,* 1999).

Carrot pomace

After extraction of juice, approximately one-third of the raw material remains as pomace. It contains 7–8% CP and 1.8% EE. It is a rich source of total sugars (64.3%) and contains about 4.3% total phenolics. Dried carrot pomace could be used up to 50% in growing rabbits diets without any adverse effects on the productive performance, nutrient digestibility and blood components (El-Medany *et al.*, 2008).

7 Carrot pomace ensiled with wheat straw

Potato *(Solanum tuberosum L.)*

During the peak production season, it becomes a problem for the farmers to dispose of the surplus and the cull potatoes. These cannot be dumped, even in the waste land, because of the legal implications. Also, such potatoes cannot be kept in the cold stores because of the cost involved. The only option for the farmers is to feed them to the livestock. Raw potatoes are not very palatable and have a laxative effect and, therefore, should be introduced gradually in the diet of animals. To get the most value from the starch present in potatoes, these should be boiled or steamed. Potato sprouts contain an alkaloid, solanine, and it is advisable to remove the sprouts before the potatoes are fed to pigs or poultry. Fungal infested potatoes should never be used as feed. The fresh potatoes contain 65–75% starch (depending on the variety), 9.5% CP and 0.4% EE on dry matter basis. Potatoes contain negligible quantities of fibrous fractions like NDF, ADF and cellulose.

8 Potato fed to cows

Dairy and beef cows can be fed up to 15–20 kg/day of raw potatoes without any adverse effects on the health of the animals (de Boever *et al.*, 1982). Pigs are usually given only cooked potatoes, which are efficiently used by fattening and breeding animals. Pigs can be fed up to 6 kg a day. Potatoes produce firm pork. Cooked potatoes can be used for poultry up to 40% of the total ration (Edwards *et al.*, 1986).

Sarson saag waste

Sarson saag, a vegetarian dish, is prepared by steam cooking of leaves of *Brassica campestris* (Mustard), *Spinacea oleracea* (Spinach) and *Trigonella foenum-graecum* (Fenugreek) in a 95:4:1 ratio. The chopped leaves are steam cooked after thorough washing. The contents are then transferred into a pulper for making pulp. The pulp is cooked with butter oil, condiments and then packed in sterilized cans while hot and is used as a delicacy for human consumption in India and abroad. The waste material left after extracting the pulp (which constitutes about 50% of the original leafy vegetables) is called 'Sarson saag waste' (SSW). SSW contains 14.5% CP and is a good source of water-soluble sugars (6%). Adult buffalo can consume 50–55 kg fresh SSW/day. The N-excretion as % of nitrogen intake was low (P<0.05) in animals fed SSW as compared with either of the conventional feeds tested, resulting in both higher (P<0.05) N-retention and apparent biological value (Bakshi *et al.*, 2005).

9 Sarson saag waste plup

Sugar beet leaves

The sugar beet leaves contain 22% CP and 3.5% EE. The leaves are rich in total soluble sugars (24.9%). The fractionation of true protein revealed that concentration was in the order: albumins > glutelins > globulins > prolamins. The leaves are a rich source of both macro and micro elements, except that the Mg and Na contents were higher than the maximum tolerance limit for ruminants. However, due to the presence of oxalic acid, which may cause scouring, fresh leaves and crowns should not be fed at levels >10 kg/day, while ensiled leaves should not be fed at levels >15 kg/day to cattle and >2 kg/day to sheep.

Sugar beet pulp

The residue after juice extraction, known as sugar beet pulp, is dried and sold as dried sugar beet pulp or mixed with molasses to form dried molasses beet pulp. The sugar beet pulp contains 10% CP and 1.1

10 Sugar beet plup

%EE with 2.36 Mcal ME/kg DM and 1.38–1.47 Mcal NE/kg DM for lactating dairy cows. Fresh pulp can be given to dairy cows and bullocks at levels up to 12 and 24 kg/day. The dried beet pulp can be fed up to 3.5 kg/day to milking animals, 5.5 kg/day to fattening cattle and 0.5 kg/day to 4 month old calves. As dried pulp readily absorbs water and swell, it should be soaked in two or three times its weight of water, especially if large amounts are to be fed to horses or calves.

Pigs digest the beet pulp fibre well, but the pulp is so bulky that total food consumption and performance will be depressed if >0.5 kg/day is fed to fattening pigs or >1 kg/day is fed to sows. Pigs relish the moist soaked pulp once they acquire a taste for it. Young pigs do not thrive on the pulp and may cause scouring because of the high oxalic acid content and contamination by the soil. Beet pulp has proved to be unsatisfactory for poultry.

Tomato *(Lycopersicon esculentum* Mill.*)*

Tomato waste is made up of culled tomatoes and tomato pomace. The culled fruits may be damaged, diseased, too small, misshapen etc. and do not meet the grading standards for sale in the fresh market or for processing. Tomato pomace is a mixture of tomato peels, seeds and small amounts of pulp that remains after processing of tomato and is fed after sun drying and grinding. Unripe tomatoes and the green parts of ripe tomatoes contain a solanine-like alkaloid (saponin) called tomatine that may be toxic to insects, dogs and, to a lesser extent, herbivores (diarrhea, vomiting, intestinal irritation). However, it disappears as the tomato ripens and is not a problem in tomato pomace.

11 Tomato Pomace Waste

Cull tomatoes - Fresh culled tomatoes contain 14–20% CP, 4–5% EE and 22% ADF. Tomatoes contain 40–60% non-structural carbohydrates; 90–95% of them are soluble sugars and 5–10% pectins. Cull tomatoes are slightly more digestible that tomato pomace as they contain all the highly digestible pulp and less fibre. Cull tomatoes are slightly more digestible that tomato pomace as they contain all the highly digestible pulp and less fibre. Fresh cull tomatoes can be fed up to 1.5 kg to male goats with *ad lib* ryegrass hay without digestive disorders (Ventura *et al.*, 2009). Dried cull tomatoes satisfactorily replaced alfalfa meal at 3 % of the diet for broilers.

Tomato Pomace - Tomato pomace (TP) can be fed fresh or can be 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 or rice straws or maize stovers in 70:30. TP contains 19–22% CP and 11–13% EE. It is a good source of lycopene, a pigment that gives colour to meat, and is a known antioxidant.

In multiparous dairy cows (26 kg milk/day) dried tomato pomace could be included up to 32.5% in the concentrate mixture without any adverse effect on health, milk yield and DM intake (Belibasakis, 1990) while sun dried, ground TP could replace the concentrate mixture completely in the diet of male buffaloes without affecting DM itake, digestibility of nutrients, urinary purine derivatives, microbial protein synthesis and total volatile fatty acids (VFAs) production in the rumen (Bakshi *et al.*, 2012).

Fresh TP can be used at 6% and 35% as a supplement feed in grower and finisher pigs respectively without any adverse effect on their performance and by decreasing feed cost/kg gain. Dried TP can be introduced up to 20% in the diet of growing rabbits without significantly affecting performance (Sayed & Abdel-Azeem, 2012). The sun dried, ground TP incorporated beyond 5% in the iso-nitrogenous and iso-caloric diets of day-old commercial broiler chicks revealed that during the starter phase the gain in weight was depressed significantly, while during the finisher phase the chicks could tolerate TP up to 10% level. Overall, the TP up to 5% in the diet did not show any adverse effect on the feed intake, gain in weight or feed conversion efficiency of broiler chicks (Sethi, 2012). Dried tomato pomace can be included up to 10–20% without any adverse effect on egg production, body weight (Calislar & Uygur, 2010) and overall egg quality (Salajegheh *et al.*, 2012), while higher levels may depress hen-day production (Jafari *et al.*, 2006).

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