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Review Article

The Potentiality of Major Crop's by Products as Livestock Feed in Bangladesh- A Review

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Abstract | In Bangladesh, large-scale animal production (cattle, buffalo, sheep, goats, and poultry) is generally based on commercial feeds rather than the provision of fodders and forages. Marginal and small farmers, on the other hand, feed their livestock with different crop residues and grasses. The feed milling industry is remarkably dependent on imported concentrate feeds for the animal ration. In addition, there is an ongoing competition of grains between animal feed and human consumption due to the excessive demand for simultaneous growth of livestock industry and human population. In our country, the production of the main crop's (rice, wheat, corn, legumes, and oilseed) is enormous all year round which offers a great opportunity to use the by-products of these main crops as animal feed (both concentrate and roughage) commercially if proper ways are followed. Feed resources are in abundance, but these are considered a waste because they pollute our environment. To maintain environmentally friendly animal production, it is highly appreciated to commercialize these by-products in such a way so that large and small-scale farmers can take over the advantages of animal husbandry. The coordination among government livestock extension departments, non-governmental organizations, and research associations is highly noteworthy for raising awareness among farmers and feed manufacturers. Hence, this review article is written to emphasize the value of major crop's by-products in Bangladesh under the scheme that highlights homegrown food as feed and not waste.

Keywords | Livestock, Crops by-products, Livestock feed, Animal production, Bangladesh

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INTRODUCTION

Bangladesh is an agricultural country and its economy is mainly based on agriculture. Crop and livestock production have a significant contribution to the economy of agriculture (Rahman, 2017). In the period 2019-20, the contribution of agriculture including livestock to the GDP is around 13.02% and the growth rate is estimated at 3.11% (BBS, 2020a). In the crop production of Bangladesh, rice, maize, wheat, oilseeds, and legumes are the most important crops in this context. While rice is the primary and most important staple food, the second and third important crops are wheat and corn. Oilseeds and legumes are also indispensable as these provide vegetable proteins and fats for the rural population (Timsina and Gulipart, 2013).

In Bangladesh, livestock farming can be characterized by friendly agro-climatic conditions, different animal species, and the integration of livestock production into agriculture with the involvement of small and large farm holders. The competition between livestock and land to produce food has increased for the rapid population growth. Nowadays, it is difficult to find available land resources in our country for growing feed or developing pastures for animals. In addition, the excessive demand for animal feeds and a change in animal husbandry are prompting the feed industry to produce quality feeds to maintain animal production (Banglapedia, 2021a; Sarker, 2019; Kazi, 2017).

As a rule, high-quality concentrate feed for livestock can be produced from pulses, coarse grains, tuberous crops, roots,

and the by-products that arise during grain processing for human consumption. Generally, these feeds come from the main crops such as rice, corn, wheat, oilseeds, and legumes that are produced by small farmers in remote and marginal areas (Huque and Sarker, 2014; Timsina and Gulipart, 2013). The rapidly growing demand for animal feed in our country offers the opportunity to utilize these by-products of the main crops and to commercialize them for the promotion of the farming economy and rural development.

This review article provides the current scenario of major crop production and the ability to use the by-products as animal feed, highlighting the nutritional quality of each by-product. The information will be very helpful in encouraging feed manufacturers and the feed industry, even small and marginalized farmers, to appropriately use these valuable byproducts as animal feeds in proper ways.

Production of major crops in Bangladesh

In Bangladesh, rice, wheat, corn, legumes, and oilseeds are known as the main crops due to their large annual production. Rice is the main staple food for the people of Bangladesh. After the Great War of liberation in 1971, rice production changed dramatically. Almost every region of Bangladesh produces a large amount of rice every year (Alamgir, 2019). Wheat is the second-largest important crop in Bangladesh (Hossain et al., 2013). It is the oldest grain but it was produced in Bengal in 1930-31. Wheat production in Bangladesh has been expanding for years. In particular, Rajshahi, Rangpur, and Dhaka are the most important regions in Bangladesh for wheat production (Table 1). Wheat production is considered as the second alternative culture just after rice. Wheat is mainly used for baking purposes in Bangladesh but the by-products such as bran, grain, and vegetative parts are also valuable components for poultry and livestock feed (Banglapedia, 2014a). Based on the phenomenal growth of corn production, Bangladesh is currently looking forward to a further increase in the production and acreage of the third key grain. Higher farm profits, proper policies, and a thriving feed industry have supported annual corn production which increased seven-fold from 0.75×10^6 tons in 2009 to 4.4×10^6 tons in 2020 (Dhaka Tribune, 2020). Therefore, after repeatedly receiving bumper production at an excellent price, farmers are interested in growing corn. The corn-growing regions in Rangpur, Kurigram, Gaibandha, Lalmonirhat, and Nilphamari are marked as the northern part of Bangladesh (Dhaka Tribune, 2019). In 2020, corn production for Bangladesh was 4.4 million tons. In the past ten years, corn cultivation in Bangladesh has grown significantly from 1.954 to 4.4 million tons at a rising rate that reached the highest value of 17.14 percent in 2019 (Knoema, 2020). In Bangladesh, lentils (masur), green gram (mung), black gram (mashkalai), gram (chola), grass pea (kheshari), and pea (motor) are popular legumes. Legumes are edible dried seeds that are grown annually in Bangladesh (Banglapedia, 2014b). Since the pulses are legumes, they are rich in proteins and minerals. It also provides carbohydrates and fats (FAO, 1994) that can be used for animal feeding. Oilseeds are one of the most important sources of vegetable oil. It plays an important role in the agricultural sector of Bangladesh. Mustard, soybeans, and linseed are the oilseeds common in Bangladesh. The production of the main crops (rice, wheat, corn, legumes, and oilseeds) in different regions of Bangladesh in the period 2018-2019 is shown in Table 1.

The immense production of important crops throughout the year in Bangladesh also generates a huge amount of by-products that have a chance of being used as animal feed not only for marginal and small farmers but also for large commercial farms. Therefore, the value of these by-products should be well known and dispersed among farmers and milling industries.

Nutritional value and importance of major crop by-products as animal feed

Rice

Rice is the main food in Bangladesh. The processing and grinding of rice produce sustainable and edible by-products,

Table 1: The production of major crops in different regions of Bangladesh in 2018-19 (Metric tonnes).

Regions	Rice	Wheat	Maize	Pulse						Oil seed		
				Lentil	Green gram	Black Gram	Chick pea	Grass pea	pea	Mustard	Linseed	Soybean
Barishal	2121979	6441	3721	3532	19183	590	1441	42789	40	2175	80	7572
Chattogram	4967089	7452	97093	1650	1621	964	79	7410	570	22018	33	103209
Dhaka	4477262	181355	239453	52157	1023	10160	820	33081	2819	59694	1290	0
Khulna	4991683	95218	753801	60480	2242	2352	493	19561	1886	30401	1254	0
Mymensingh	4096741	21317	108287	783	120	3232	81	520	86	14573	67	0
Rajshahi	5982446	403614	421689	54775	9563	22685	2243	12181	1983	147417	502	0
Rangpur	6458898	298624	1945214	1852	345	2807	186	1138	48	31504	368	1
Sylhet	3151860	2707	63	155	5	497	4	38	7	3958	47	0

Source: BBS, 2020b.

such as bran, which can be used as animal feed. Rice bran is the most preferred because it contains functional properties. It consists of fat, protein, crude fiber, and ash. Rice straw is another byproduct of rice after harvesting rice. The nutritional properties of rice bran are highlighted in Table 2.

Table 2: The nutritional composition of rice bran based on the dry matter (%).

Nutrient	Percentage (%)
Acid detergent fiber	20
Neutral detergent fiber	33
Crude Protein	14.4
Ether Extract	15
P	1.73
Ca	0.1
Ash	11.5

Source: Gadberry *et al.*, 2007.

Rice bran has prebiotic properties that can prevent colonization with *Salmonella* in the digestive tract (Bodie et al., 2019). The bran is considered an important by-product as it contains 14-18 percent oil. In compound feed, defatted rice bran is a useful binding agent that, compared to ordinary bran, can be incorporated very well (Heuzé and Tran, 2015). The germs and bran from rice processing make up 10 percent of the rice grain, which contain enormous nutritional properties. It is a very valuable ingredient in feed formulation because it contains 30-40% digestible carbohydrates, 14-18% oil, and 15-18% protein. The composition of the rice bran depends on the type of rice and the grinding capacity. The amount of bran, rice hulls, polished rice, and broken rice after grinding is 10%, 20%, 50-60%, and 1-17%, respectively. Pollard is a mixture of polish and bran that contains approximately 5% polish, 60% hulls, and 35% bran. The rice bran is an effective ingredient for using as a feed for laying hens and broilers with an inclusion level of 1.5-2% (Benjamín, 2016). One experiment found that rice gluten meal at 464 g per kg of crude protein could be successfully incorporated into the concentrate mix, replacing 75 percent of groundnut cake with no apparent compromise in growing claves' performance (6 to12 months). Rice gluten meal can be incorporated as a substitute source of groundnut cake for the economical rearing of lactating claves. It will reduce the dependence of commercial farmers on conventional sources of protein (Kumar et al., 2016).

Rice straws are an inexpensive, readily available, and practical source of livestock feed for ruminants (cattle, buffaloes, sheep, and goats). Animal producers often stack straw for animal feeding while roughage is scarce. Feeding rice straw to livestock during early lactation and in rapid growth stages affects animal performance and body condition due to the low protein percentage (3-6%). The high lignin and silica content of straw also affects the digestibility of protein and dry matter. Therefore, straw pre-treatment is essential to realize its potentiality to improve milk and meat production. Farm-based technology can be developed to optimize the feeding and nutritional value of straw. The focus is on the recycling, enrichment, and pre-treatment of rice straw using biological, chemical, and physical processes. Physical treatment is an inexpensive and viable method to improve the recycling and utilization of the nutrients in rice straw as livestock fodder. It aims to improve the ingestion, digestibility, and palatability of livestock animals. Physical treatment includes milling, soaking, pelleting, gamma irradiation, and steaming pressure. The chemical process has been studied to enhance the nutrients in straw and improve animal performance. The biological process includes various microorganisms such as fungi, bacteria, and enzymes. Different strains of fungi can enhance the degradability through the effect on the cell contents of rice straw (Zayed, 2018; Madzingira et al., 2021; Zhang et al., 2018).

Wheat

Due to frost, insects, and disease damage, wheat is an unsuitable and low-quality milling grain. Wheat is mainly used as animal feed. The by-products that can be obtained from wheat milling are wheat bran, wheat pollards or middlings, brown shorts, germ, and red dogs which are the resources of animal diet due to a variety of nutrients. The nutritional value of various wheat by-products is shown in Table 3. Bran is the outer cover of the wheat kernel. The wheat pollards or middlings are the particles of red dog, germ, and bran. Shorts can be brown in color, consisting of flour, germ, tailings, and bran. Red dogs are small particles, also known as light shorts that consist of flour, germ, and bran. Germ is generated during the grinding process of milling (Ontario, 2021).

Table 3: The nutritional composition of wheat by-products based on the dry matter (%).

Nutrient	Wheat gluten	Wheat bran	Wheat germ	Wheat pollard or middling
Dry matter	91.4	88.7	88.7	89.4
Crude fiber	0.5	12.3	3.5	7.8
Crude protein	80.1	15.6	28.5	16.9
Crude Ash	0.7	5.6	4.9	4.7
Crude fat	1.5	4.7	8.8	4.4
Nitrogen free extract	17.2	61.8	54.3	66.2

Source: Hertrampf and Piedad-Pascual, 2000.

The by-products of wheat have some effective uses in the formulation of pig and poultry feed (Slominski et al.,

2004). Wheat gluten is a less expensive and high protein source that can easily be replaced by conventional protein sources. Wheat gluten can be included in the broiler diet as a pre-starter to suppress the allergenic actions of soybean meals and to boost the digestibility of protein. Its major utilization is in calf milk replacer as an inexpensive alternative to casein, milk protein (Efstratia, 2020).

In milk production, wheat bran could be the sole substitute of cereal grain in forage-based feeding systems during the mid-lactation without impairing the dairy cow's performance (Ertl et al., 2016). Wheat bran provides digestible fiber that can fulfill the daily requirement of the ruminants. About fifty percent of wheat bran can replace barley and corn in the diets of sheep and lamb. Wheat bran enhances the feeding value and suppresses the degradation of protein in the rumen that improves the performance of the animal. It contains sugars and starches that are essential for animals to grow properly. It improves the digestibility and metabolic activities of ruminants. Wheat bran production and the process of pelleting provide an effective framework for producing high-quality pellets for animal farmers (George, 2012). The palatability and laxative properties of wheat bran are satisfactory that can be given in adequate quantities to poultry, pigs, horses, sheep, and cattle (Table 4) but should be restricted to young stock (Riverina, 2015). Wheat bran is an economical and nutritious animal feed. The fermented bran from *Bacillus cereus* (xylanase-producing) can partially replace 5% corn in which has no side effect on growth performance and can improve the intestinal microflora and amylase activity in the broiler. Therefore, fermentation is a feasible approach to the pre-treatment of bran in the feed industry (Feng et al., 2020).

Wheat germ is a yellow, brown, and creamy white fibrous feed ingredient, in granular form that is produced by separating, compressing, and crushing processes. It is a good supplement in animal feed as it is high in protein and energy (Bunge, 2021). To improve feed efficiency, five-gram of wheat germ can be added to the diet of individual growing goat every day (El-Tarabany et al., 2013).

In cattle feeding systems, wheat midds are an alternative to forage because forage contains low protein. It can be supplemented in a ruminant diet compared to monogastric because it contains a significant amount of digestible fiber and starch. Because of the rapid breakdown of the starch content, it should be limited to 50% of the dry matter (Poore et al., 2002).

Wheat straw is a source of roughage. It can be used in stud cattle and horse rations (Riverina, 2015). Although wheat straw does not contain high energy or protein, it can be used as a supplementation in the diet of breeding cows, with 5 or 6 BCS (Body Condition Score). It can also be added to the diet of calving cows. About 50% of wheat straw and 50% of legume hay or grass as a dry matter basis can be supplied in mature bred cows (David, 2011). Treatment of wheat straw by *Crinipellis* sp. (Fungus RCK-1) has the potential to break down lignin and improve nutrient levels, which can replace 50% grain and can be used as animal feed. Wheat straw can be utilized as the primary roughage in the ration of dry and lactating cows. It can be added as 2/3 of wheat straw with the combination of high-quality grass for the dry cow. It can replace 1/3 of the lactating cow ration with good-quality hay. It is a feasible forage that extends feedstocks and also lowers the costs in the dry years. It can be a partial source of forage in the diet of finishing and growing cows. It should be chopped no more than 1 inch before mixing it into the ration (Shrivastava et al., 2014; Beef Cattle, 2019).

Table 4: The inclusion level of wheat bran and wheat straw in different species.

Species	Maximum inclusion level	
	Wheat bran	Wheat straw
Cattle	50%	40%
Sheep	50%	20%
Goat	-	20%
Horse	50%	30%
Poultry (layer)	15%	-
Poultry (Broiler)	10%	-
Pig (Growing stage)	15%	-
Pig (finishing stage)	25%	-
Pig (breeding stage)	30%	2%

Source: Riverina, 2015

Maize

In Bangladesh, corn is used for two distinct purposes. It is mainly used as a feed ingredient for fish and livestock, and human consumption as corn flour and popcorn (Dhaka Tribune, 2020). The by-product after harvesting corn known as maize stover, is utilized as fuel in rural areas and contributes to greenhouse gas production. But this maize stover has the potentiality to be used as animal feed. It is an important source of fiber, especially for ruminants. As the maize stover is available in large quantities and mostly can be fed mainly to cattle, goats, and sheep. It can be offered as a whole plant alone or chopped and mixed with other green forages (Lallemand Animal Nutrition, 2021).

Corn stover is a resource in mixed farming systems. It can be utilized for fodder and silage production (Pandey et al., 2017). It contains a higher amount of digestible and other nutrients (Table 5) that are essential for animal feeding. In addition, pre-treatment of corn stover with physical and

microbial inoculation such as *Phanerochaete chrysosporium* and *Penicillium decumbens* improves the protein content (12.71%) and reduces feed shortages in animal production (Sun et al., 2018). Corn stover fermentation with fungus such as *L. edodes* or *P. eryngii* for 28 days can enrich the nutritional value due to the degradation of lignin for the ruminant feed (Zhao et al., 2020). The co-fermentation of rice straw and corn stover with enzymes and probiotics improves the rumen efficiency in the beef cattle feeding system (Hu et al., 2020). Ensiling corn stover with vegetable waste provides an optimistic strategy to preserve the stover of an animal feed for a longer period (Ren et al., 2020). The nutritional composition of different by-products of maize is shown in Table 5.

Corn cobs are the by-product of corn crops. The meal of corn cobs is a great source of feed for livestock and cheaper compared to other meals. It contains all the nutritional values (Table 5) and 1 kg of corncob meal can provide animals with 4,000 calories (Kanengoni et al., 2015). Maize cobs, green, and dry maize stalks can be used together with rice bran, wheat straw, alfalfa, oilseed cakes, grasses and forages, hay crops, tree leaves, shrubs, molasses, vegetables, and fruits pulps. Sometimes a single item can be included alone or a combination of two or more items can be prepared to be used as feed for farm animals (All about feed, 2015). Corn cobs are the carriers of antibiotics and vitamins in livestock feed (Heuzé et al., 2016a). The high fiber corn cob has excellent potential as a pig feed as it increases nutrient retention by improving the passage. Pigs can intake up to twenty-five percent of the energy required for maintenance. Moreover, the dietary fiber of corn cobs can improve the intestinal health of pigs by promoting the growth and the development of lactic acid-producing bacteria, which inhibits the proliferation of pathogenic bacteria in the small intestines (Kanengoni et al., 2015). In addition, ground corn cobs can be utilized as a source of roughage in a total mixed ration with 60% concentrate feed, which significantly improves nutrient uptake and milk production in lactating Holstein crossbred cows (Wachirapakorn et al., 2016).

The other by-products after the wet milling of corn are endosperm, germ, and bran. The corn by-products including germ, gluten, and bran, are effective and suitable as feed for farm livestock. Moreover, corn gluten is particularly rich in metabolizable energy, xanthophylls pigments, and proteins, which are the potential feed for poultry production (Dei, 2017).

Legumes

Legumes play a significant role in animal feeding systems by providing valuable by-products that contribute to food security. The use of legume by-products such as other plant parts and straws that are leftover just after the harvest of seeds has considerable potential for use as ruminant feed. In addition, the endosperm fractions, husks, and seed coats obtained from processing legumes for human consumption are also a good source of animal feed. The by-products of legumes are rich sources of energy and protein. They contribute to reducing soybean and cereals levels in livestock diets. They can be utilized by small farmers in times of feed shortage as mixed livestock farming. Legume by-products also offer important environmental, social, and economic advantages by extenuating grains used in animal feeding systems (Calles et al., 2019).

Table 5: The nutritional composition of different maize by products.

Nutrient	Maize stover (%)	Maize cob (g/kg DM)	Maize endosperm %	Maize tip cap %	Maize pericarp %	Maize-Germ %
Dry matter	82.50	908.3	-	-	-	-
TDN (Total digestible nutrient)	50.6	-	-	-	-	-
Crude Protein	5.45	38.9	73.8	0.9	2.6	26.2
Crude Fiber	34.06	286.9	-	-	-	-
Ether Extract	1.45	5.7				
Nitrogen Free Extract	50.79	-	-	-	-	-
Ash	8.24	76.7	17.9	1.0	2.9	78.4
NDF	-	706.3	-	-	-	-
ADF	-	515.8	-	-	-	-
Acid detergent lignin	-	168.8	-	-	-	-
Hemicellulose	-	190.5	-	-	-	-
Cellulose	-	347.0	-	-	-	-
Starch	-	-	97.8	0.1	0.6	1.5
Sugar	-	-	28.9	0.8	1.2	69.3
Oil	-	-	15.4	0.8	1.3	82.6
Reference	Khan, 2008	Kanengoni *et al.*, 2015	Dei, 2017			

Table 6: Nutritional composition of lentil by-products (on DM basis).

Nutrients	Straw (%)	Screening (%)	Pod Husk (%)	Bran (%)
Dry matter	90.4-93.8	87.9-90.4	88.0	87.6-91.1
Crude fiber	29.9-41.1	5.3-19.4	29.0	8.4-32.2
Crude protein	5.8-8.6	22.7-25.9	12.6	15.0-26.4
Ether extract	0.8-2.2	1.7-2.6	0.8	0.6-1.4
ADF (Acid detergent fiber)	27.1-51.3	10.9	-	35.9-48.6
NDF (Neutral detergent fiber)	42.8-71.0	20.9	-	48.6-53.0
Ash	6.0-11.2	3.8-10.7	3.5	2.8-9.8
Lignin	5.9-13.3		9.6	7.4
Phosphorus	0.11-0.19	0.47	-	0.22-0.56
Calcium	1.50-3.01	0.20	-	0.51-0.82

Source: Feedipedia, 2016

Lentil ranks first position in Bangladesh in terms of consumers' preference and second place in terms of area and production. It is an important source of protein in the daily diet of most people in the country (Uddin et al., 2013). The lentil by-products have a nutritional value (Table 6) that can be used as animal feed.

The screenings of lentil are the waste products after cleaning the lentil seeds, which consist of cereal grains, broken and whole lentils, chaff, weed seeds, and dust (Stanford et al., 1999). However, good quality lentil screenings can be used as a source of energy and protein-rich feed for animals (Lardy and Anderson, 2009) as they have a good crude protein content of approximately 25% based on DM. Lentil screening can be used in hay and silage or pelletized form as feed (Feedipedia, 2013a; McKinnon, 2018).

During dehulling, the outer coverings of lentils have yielded lentil bran which is mixed with hull and chuni. It contains 21.8% dietary fiber (DM basis), which is higher compared to screenings and seeds. However, when a mixture of 50% wheat bran and 50% lentil bran was fed as feed for the bull, the fermentation in the rumen improved (Feedipedia, 2013b; Gendley et al., 2009).

Lentil straw is produced after threshing lentil seeds, which is high in fiber (30-40%) but has a low crude protein content of less than 10% based on DM, which is better in quality than wheat and other cereals (Lardy and Anderson, 2009). Lentil straw contains lower NDF content, which is highly degradable in the rumen and whole tracts compared to cereal straws (Haile et al., 2017). The use of lentil straw in total mixed ration improved the organic matter, the nitrogen-free extract, and the dry matter digestibility. The researcher suggested that the use of lentil straw can be used ad libitum or with a mixed total ration to improve kid's performance (Mudgal et al., 2018). Therefore, lentil by-products (bran and screenings) can be included in the feeding system of ruminants. Moreover, the straw from lentils can be supplied as feed for grazing animals (Haile et al., 2017; Venkidasamy et al., 2019).

Green gram is an annual plant that grows rapidly during the warm seasons. The plants reach their maturity quickly in subtropical and tropical conditions. The most productive area of green gram is Barishal followed by Rajshahi and Khulna. Sylhet is the least grown region in Bangladesh for green gram. The nutritional properties of green gram straw and other by-products are shown in (Table 7).

Table 7: Nutrient components of green gram pulse by-products (Dry matter basis).

Parameter	Endosperm, husk, and seed coats %	Straw %
Ether extract	2.2	2.3-2.4
Crude protein	19.2	8.7-11.6
Crude fiber	26.2	26.6-29.9
ADF (Acid detergent fiber)	26.4	32.0-47.2
NDF (Neutral detergent fiber)	43.5	63.5
Ash	4.8	6.1-12.1
Phosphorus	0.3	0.2
Calcium	0.4	2.7
Lignin	4.3	4.8
DM	95.3	88.2

Source: Feedipedia, 2016

Green gram hulls, endosperms, and seed coats can be added 50% ratio with rice straw as buffalo feed. It does not adversely affect the utilization and maintenance of the requirements. 14% and 18% inclusion of green gram hull can be added in the ration of laying hen as it has no detrimental effects on production (Vinh et al., 2013). The hull leftover from the green gram's husk can be used extensively as ruminant feed. In broilers, 5% green gram hull can also improve digestibility and growth (Rungcharoen et al., 2010). The green gram plant is a valuable forage that

can be fed to animals as silage, hay, or straw (Banglapedia, 2021b; Vikaspedia, 2020). 100% of the green gram grass can be included in the sheep ration without any adverse effects (Garg et al., 2004). The straw from green grams can be mixed with wheat and rice straw and used as goat and sheep feed. Green gram straw is palatable and has no deleterious outcomes in animal health. Green gram straw can be added to a goat's complete feed block with the addition of yeast (Nehra et al., 2014).

Black gram is also a leguminous crop that is cultivated as a valuable legume in Bangladesh (Banglapedia, 2015). The straw and other by-products from black gram are full of nutritional qualities that make them a good resource for animal feeding (Table 8).

Table 8: Nutrient composition of black gram by-products (based on Dry matter).

Nutrients	Straw (%)	Chuni (%)	Husk (%)
Dry matter	90	93.1	-
Crude fiber	28.6	13.1	20.3
Crude protein	8.9–17.2	20.7	18.2
Ether extract	0.4–2.8	2.2	1.4
ADF (Acid detergent fiber)	31.9–36.4	-	37.4
NDF (Neutral detergent fiber)	54.5–56.9	-	48.2
Ash	8.8–12.6	11.7	5.5
Lignin	4.6	3.0	9.6
Phosphorus	0.16	-	0.26
Calcium	1.74	-	0.51

Source: Feedipedia, 2016

In Bangladesh, black gram or khesari can be cultivated as pasture with grass pea without any tillage system. The CP (crude protein) content of khesari straw is highly digestible than Leucaena leaves (Singh et al., 2002). The different ratios (318, 212,106, and 0 g dry matter) of khesari with the supplementation of straw can increase the nutrient digestibility, the live-weight gain, and the feed intake of indigenous or deshi bull calves at the age of two to three years (Hossain et al., 2015). However, the use of khesari straw supported the growth of sheep as it made up 60% of the diet and gained an average of 60 to 62 grams of live weight daily (Jadhav and Deshmukh, 2001). The khesari foliage can be mixed with all or 50% wheat bran which improves milk production, fiber digestibility, and feed intake in hybrid milking cows (Dey et al., 2016). In the diet of buffalo bull, the addition of 40% khesari chuni in rice straw has a positive influence on the digestibility of the dietary fiber (Reddy et al., 2000).

Chickpea or gram is the most important legume. Chickpea is an annual legume crop known as gram or chola (Roorkiwal et al., 2020). Chickpea is a quick-growing plant that reached 20-60 cm in height. The stems of the gram are simple, hairy or branched, curved or straight. Rajshahi and Barishal are the top gram-producing areas in Bangladesh. There is a future hope that gram's by-products will be incorporated as livestock feed in Bangladesh. Chickpea is considered a legume with little labor and requires less input than other grains. It is considered an important legume crop, especially in mixed livestock-crop cultivation. Chickpeas are produced in particular as feed and fodder legumes, with the products simultaneously providing nutrition for livestock and humans. In mixed livestock-crop operations, the shortage of fodder is common and gram by-products can be a potential outcome for obtaining greater benefit to the livestock. The nutritional composition of chickpea or gram by-products is represented in Table 9.

Table 9: The nutrient composition of chickpea or gram by-products based on the dry matter.

Nutrients	Straw %	Pod husk (%)	Bran (%)
Dry matter	92-93.4	86.8-88.0	84.4-91.0
Crude fiber	31.4-50.6	48.4	22.3-31.1
Crude protein	2.8-8.8	3.5-10.5	12.5-18.5
Ether extract	0.5-1.6	0.9-3.0	2.8-4.2
ADF (Acid detergent fiber)	33.0-59.6	46.9-65.2	35.3
NDF (Neutral detergent fiber)	46-78	56.7-76	43
Ash	3.8-13.3	3.8-7.3	5.1-7.0
Lignin	8.5-15.8	3.3-7.1	-
Phosphorus	0.05-0.44	-	0.27-0.32
Calcium	0.34-1.36	-	0.67-1.56

Source: Feedipedia, 2016.

The main by-product of chickpea is straw, which is obtained after the grain has been threshed. Chickpea straw can be introduced as livestock feed. It contains 44-46% TDN (total digestible nutrients) and 4.5-6.5% CP based on dry matter compared to cereal straws. Chickpea straw has 7.7 MJ/kg metabolizable energy (ME) and is relatively higher than wheat straw (5.6 MJ/kg metabolizable energy). The rumen degradability and dry matter digestibility (DM) of the straw are 42% and 10% higher, respectively than other types of cereal straws. The metabolizable and digestible energy of its straw are 7.7 and 8.3 MJ/kg dry matter (DM), respectively, which suggests that the chickpea straw has great potential to be used as an alternative legume forage for the ruminant animals (Maheri-Sis et al., 2011).

The chickpea bran is also considered a valuable by-product collected after the processing of chickpea. The by-product contains the broken piece of husk and germ. It contains 13-

19% crude protein (CP) based on dry matter, an excellent protein content. The bran provides 164 kcal of energy per 100g of bran. It serves as a source of energy and protein for livestock animals. The bran has been shown to contain all the essential elements for ruminants for proper growth and milk production. It can be used in the diet of non-ruminants as a whole meal as it promotes meat growth and egg production (Royal Flour Mills, 2020).

The ADF and NDF content of Chickpea husk based on the dry matter are 65.2% and 76.0%, respectively. Tannin binds a small proportion of chickpea husk carbohydrates, which is conserved during fermentation but digested considerably in the small intestine. The husk of the chickpea has over 94% rumen digestible dry matter fraction. In wethers and lambs, at the age of 6–8-months, the husks of chickpea can be incorporated into 10-20% of the ration (dry matter basis), which can replace rice straw or rice bran, increasing the degradability of OM, DM, ADF and NDF (Ngwe et al., 2012).

Grass pea is a legume crop, that is grown for human consumption, and as fodder for ruminant feeding (Heuzé et al., 2016b). Grass pea forage is a good source of protein containing 17% protein in mature leaves that can be used as fodder for animal feed (Lambein et al., 2019). Grass pea can be introduced in the marginal areas imparting an alternative to the hazardous animal protein source or imported soy as livestock feed. Grass pea forage is a valuable feed resource for livestock as shown in Table 10.

Table 10: The nutritional composition of grass pea's forage-based on dry matter.

Nutrients	%
Dry matter	91.4
Crude fiber	28.5
Crude protein	19.1
ADF	32.7
NDF	43.4
Ash	9.9
Ether extract	2.9
Gross energy	18.6 MJ/kg dry matter
Phosphorus	2.1 g/kg dry matter
calcium	13.3 g/kg dry matter
Energy digestibility in ruminants	64.7%
Organic matter digestibility in ruminants	68.3%
Metabolizable energy in ruminants	9.5 MJ/kg dry matter
Digestible energy in ruminants	12.0 MJ/Kg dry matter
Nitrogen digestibility in ruminants	71.7%

Source: Feedipedia, 2014

Fresh plants can be harmful to the horse but rabbits, sheep, and cattle can consume in a large amount without any side effects (Heuzé et al., 2016b). The NDF, ADF, and CP content of grass pea forage were 300.6, 397, and 232.4 g/kg dry matter, respectively. The metabolizable energy was estimated to be 6.86-12.03 MJ/kg dry matter. Moreover, the MP (metabolizable protein) was 534.7 g/kg of CP. The elevated MP, CP, and ME content of grass pea forage and straw improve the palatability that can be introduced into sheep feed during drought situations (Vahdani et al., 2014).

Pea is an important crop that can be used as feed and fodder of animal (Heuzé et al., 2017). Although the production of peas is comparatively lower than other legumes, it has a great chance of being used as fodder during natural calamities. The mixture of pea and oat forage straw has the potential to be a great option as forage for dairy and other livestock farmers (Jim, 2018) as the nutritional value is listed in Table 11. The main reason for using peas by-products is the palatability and protein content that results in the ensiled forage (Jim, 2018).

Oil seed

Mustard is the popular oilseed where the by-product of mustard, mustard cake is easy to find in Bangladesh and cheaper compared to peanut cake. Mustard seeds are a good source of protein and oil at 34-39% and 30-35%, respectively. The mustard cake is produced from the leftovers of a commercial mustard meal or oil production. It may replace expensive peanut cake and can be incorporated into growing lambs' diet as a source of protein. It contains a comparatively large amount of methionine and balanced amino acids. It can be used in buffalo and cattle feeding (Kadegowda et al., 2002). Mustard oil cake supplements the protein that is degradable in the rumen in a straw diet, which enhances the digestibility, absorption, and synthesis of microbial protein. It increases poor-quality feed (straw) utilization that may encourage the development of low-cost feeding systems in tropical areas (Khandaker et al., 2012). Bodyweight gain and milk production were higher while the cattle were fed mustard oil cake (Khare et al., 2014). It is a good source of energy for cattle because it contains 27% DCP, 74% TDN, 0.6% Ca, and 0.1% P, respectively. It may be introduced to cattle feed up to ten percent of the ration (Agritech, 2012).

The byproducts of soybean are a good source of nutrients, especially essential amino acids, and can be included in the dairy cattle ration as an excellent feed. The soybean's byproducts are suitable in any kind of forage-based feed formulation. It contains energy, fiber, fat, and high-quality protein as shown in Table 12 (Ishler and Varga, 2008). The meal generated after the production of soybean oil is an excellent source of protein for milking cows.

Table 11: The nutrient components in pea's byproducts based on the dry matter.

Nutrients	Straw %	Dried by-products (%)	Fresh by product (%)	Pod, silage (%)	Ensiled by product (%)
Dry matter	88.8	90.4	26.5	27.5-95.1	28.2
Crude fiber	36.3	17.7	22.6	12.2-56.4	24.3
Crude protein	8.2	18.6	17.8	5.7-23.7	12.0
Ether extract	2.1	2.0	2.1	0.5-3.6	3.2
ADF (Acid detergent fiber)	38.7	-	26.8	9.3-45.1	40.5
NDF (Neutral detergent fiber)	54.9	43.0	43.1	16.6-58.1	53.7
Ash	9.8	15.2	13.3	3.3-11.4	18.7
Lignin	7.2	8.0	4.7	0.4-12.9	9.3
Phosphorus	0.11	1.24	-	0.05-0.30	-
Calcium	2.37	1.27	-	0.30-1.66	-

Source: Feedipedia, 2016

It is nutritious, palatable, and highly digestible. It provides energy and protein and is low in fiber compared to other oilseed meals. In addition, soybean hulls produced during the processing of soybean, contain a good amount of digestible fiber. They are low in lignin and high in energy. In different feeding systems, they can be added up to 10 percent (dry matter basis) in the diets of dairy cattle. They have the potential to be included in both dry and lactating cow diets. Researchers found that the hulls can replace forage fiber during mid and early lactation (Ishler and Varga, 2008). Moreover, the hulls of soybeans can replace a maximum of 50% maize in the concentrate mixture which has no adverse impact on the performance and health of the growing goats (Jadhao et al., 2020).

Table 12: The nutrient components in soybean byproducts based on dry matter.

Nutrients	Soybean meal (%)	Soybean hull (%)
DM	88.0	90.0
NDF	14.0	67.0
ADF	10.0	50.0
CP	50.0	12.0
Ash	7.3	5.1
Fat	1.4	2.3
p	0.68	0.21
Ca	0.30	0.59

Source: Ishler and Varga, 2008

Linseed is the third oil-producing seed in Bangladesh. The byproduct of linseed, linseed meal, whole or ground, is a good feed resource in cattle, swine, and poultry because it contains energy, oil, and protein. It provides 70-85 percent TDN (total digestible nutrients) and 32-37 percent CP (crude protein). It can mostly be fed to young calves and horses. The meal is a rich source of omega-3 (Ω-3) fatty acids and researchers have observed that feeding the linseed meal to animals increases Ω-3 fatty acids in meat and milk (Dairy Knowledge Portal, 2014).

CONCLUSIONS AND RECOMMENDATIONS

Currently, most of the commercial animal production systems in Bangladesh can be characterized as intensive in nature. Due to the high conversion of pasture or agricultural lands into residential areas or industries, the semi-intensive and extensive production systems with the development of fodder plots and pasture areas are quite costly and troublesome. Commercial farmers are therefore directly dependent on concentrate feed and always compensate for the shortages of animal feeds and forages by supplementing high-priced imported feed. On the other hand, the small and marginal farmers restrain their livestock from feeding concentrate feeds as imported feedstuffs such as concentrates are highly expensive. They always prefer roadside grasses or plant leaves as animal feeds and are not capable of feeding their animals according to their requirements. In addition, the competition between animal feed and human food is a common barrier to animal production and profitability. These key constraining factors are currently under consideration to be solved. To address these issues, shifting to utilizing high quality home-grown crop by-products can be an efficient solution.

To improve the productivity of animals in a systematic and coordinated scheme under the mentioned scenario, it is, therefore, necessary that all stakeholders, for example, agricultural extension departments, non-government organizations, and research associations, should engage in planning, implementation, and development of sustainable livestock production. They can arrange seminars, workshops, and field meetings that can create an awareness to the commercial and marginal crop producers, feed

manufacturers, and animal farmers who are particularly involved in the unconsciousness of the values of major crop's by-products. The proper scheme in the utilization of major crop by-products is shown in Figure 1.

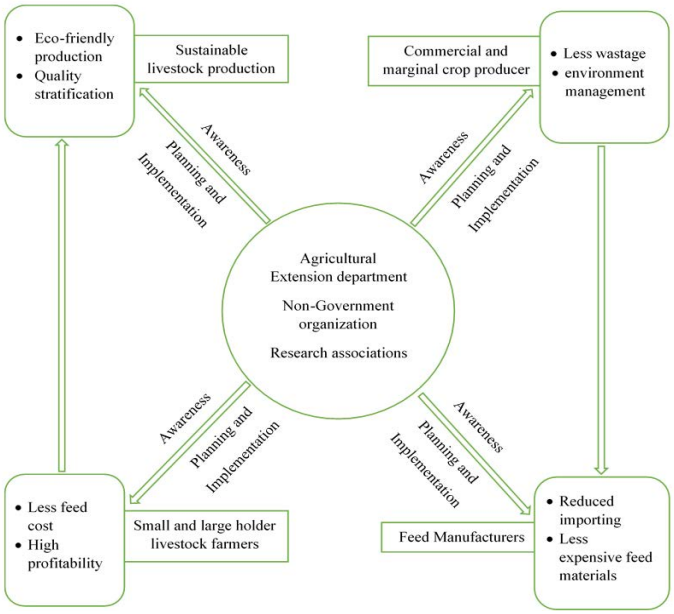

Figure 1: The operational scheme in the utilization of major crop byproducts as animal feed.

This review article has provided sufficient knowledge of the nutritional properties and feeding strategy of key crop's by-products, so that the objectives of reducing feed waste and imports can be successfully implemented and environmentally friendly livestock production can be gradually accomplished.

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NOVELTY STATEMENT

The current scenario of major crop production in Bangladesh and the ability to use these by-products as animal feed were mentioned. The nutritional quality and feeding strategy of each by-product were also highlighted. The information will be helpful for researchers to conduct the researches and find out the outcomes.

AUTHOR'S CONTRIBUTION

All authors contributed equally.

Conflict of interest

The authors have declared no conflict of interest.

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