Research Article

Ruminant Feed Production and Nutritional Evaluation by Ensiling Rice Straw, Napier Leftover, and Rumen Content

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Abstract | A study was performed to ensile rice straw, and napier leftovers with rumen contents (RC), and molasses to determine the physical and nutritional properties of silages. Silages were prepared in airtight plastic containers at ambient temperature according to the treatments T_0 (0% RC), T_1 (5% RC), T_2 (10% RC), and T_3 (15% RC) with 5% molasses as dry matter basis at 0, 14, 21, and 28 days, respectively. Results showed that the physical qualities (color, odor, and softness) of silages were improved in rumen content added treatments till 28 days of ensiling period. The pH of silages was declined ($p<0.05$) with the enhancement of RC and ensiling period. The crude protein (CP), metabolizable energy (ME), and organic matter digestibility (OMD) were improved ($p<0.05$) but dry matter (DM), crude fiber (CF), ether extract (EE), and ash were declined ($p<0.05$) in all the treatments (T_1, T_2, and T_3) compared to control T_0. In the consideration of results among all the treatments, T_2 and T_3 up to 28 days were desirable for the preparation of silage. To sum up, rumen content can be utilized in rice straw and napier leftovers in silage preparation which provides a low-cost quality ruminant feed by reducing the environmental pollution.

Keywords | Environmental pollution, Silage, Metabolizable energy, Organic matter digestibility, Physical properties

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INTRODUCTION

Livestock is an indispensable part of animal food production systems that contributes to human food security in Bangladesh (Begum et al., 2011). Nowadays, livestock farming is becoming increasingly popular and growing rapidly. The current livestock population is estimated at 412.24 million (2019-20) which was 402.56 million (2018-2019) in the previous year (DLS, 2018). Feed insufficiency is a key obstacle in livestock husbandry to fulfill the nutritional requirement of animals. Animal underperformance in Bangladesh is widespread because native grasses and low-quality roughages are used as ruminant feed (Agrilinks, 2020).

Rice straw is an inexpensive roughage that is an effective and readily available source for ruminant feeding. Livestock owners usually stack the straws after harvesting rice which incorporates as a reserved animal feed during dry periods or when there is a shortage of feed. Rice straw, which is used as ruminant feed during lactation and growth, has an impact on both animal production and body condition due to its low protein content (4-4.7%). The high lignin and silica contents of straw also influence digestibility and nutrient availability (Aquino et al., 2020). Napier grass is an important fodder in Bangladesh (Negawo et al., 2017) and is increasingly associated with the dairy and livestock sector to meet the growing demand for milk and meat (Dhaka Tribune, 2021). It is one of the most promising grasses available for ruminant production in tropical areas because of its high potential dry matter (DM) yield (Negawo et al., 2017) but a major problem of it is left as residual by animals due to the hardness of steams (Phitsuwan et al., 2016). On the other hand, the growing animal population generates an enormous amount of abattoir waste like rumen content, which burdens rural and urban areas with improper disposal and poses obstacles to humans and the environment simultaneously. Rumen content including non-fermented and fermented feed materials at various stages of digestion causes the pollution of water by entering into streams, rivers, and local water sources (Cherdthong, 2020).

The process of silage preparation is a simple method. Silage preparation through rice straw (Oladosu et al., 2016), napier leftover (Gulfam et al., 2017), and rumen content (Cherdthong, 2020) with the addition of molasses can ensure the growth and dominance of lactic acid bacteria during the process of fermentation and produce lactic acid enough to ensure good quality silage (Yitbarek and Tamir, 2014). It is a low-cost option of disposing of waste products and reducing feed costs for ruminants (Dairy Global, 2020). Ensiling of rumen content with rice straw helps to improve the nutritional value, such as by improving protein contents and reducing pH, fiber contents, and lignin due to containing ruminal microorganisms. Furthermore, the ensiling of rumen content with agro-industrial by-products increases their digestibility. Thus, ensiling of rumen content with crop residues can save the environment and at the same time meet the nutritional needs of the ruminants (Cherdthong, 2020).

Silage preparation with rumen contents has not yet been conducted in Bangladesh. As there is a huge opportunity to utilize the rumen content as ruminant feed, this article was designed to find out a convenient option and optimal ratio of rumen content, rice straw, and napier leftovers for animal feeding by improving the nutritional value through silage preparation.

MATERIALS AND METHODS

Experimental site

The experiment was undertaken at goat and sheep farm, Department of Animal Science, and chemical analysis was attained at the Department of Animal Science and Nutrition Laboratory, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.

Collection of materials

The Rumen contents were collected from Mymensingh municipality slaughterhouse. Rice straw was available at Goat and Sheep farm, and napier leftovers were collected from Shahjalal Animal Nutrition Farm laboratory, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh. Plastic containers and molasses were purchased from Notun Bazar and Swadeshi Bazar, Mymensingh, Bangladesh, respectively. After that, the containers were washed, cleaned, and dried properly. Plastic containers were labeled for various treatments.

Preparation of fresh samples for chemical analysis

The napier leftovers and rice straws were manually chopped into small pieces. Chopped naiper leftovers, rice straws, and rumen content were analyzed for determining the dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), ether extract (EE), total ash (TA) and nitrogen-free extract (NFE) of the fresh samples following AOAC (2004) methods (Table 1).

Table 1: Chemical composition of rumen content and rice straw.

Chemical composition (g/100g DM)	Ingredients		
	Rumen Content	Rice straw	Napier leftover
Dry matter % (Fresh basis)	32.4	89.1	20.0
Organic matter (OM)	74.6	82.2	81.1
Crude Protein (CP)	23.7	3.01	6.00
Crude Fiber (CF)	28.1	31.8	31.7
Ether extract (EE)	1.98	4.46	3.07
Nitrogen free extract (NFE)	41.2	31.6	35.1
Ash	12.0	18.2	14.4

Experimental design

The experiment was designed in a 4×4 factorial with 3 replicates in each treatment. The investigation was carried out to study using the fresh rumen content with rice straw for the production of silage as a feed for ruminants. The treatments in the study were as follows:

Treatments: T_0= 0% rumen content + 5% molasses + 50% rice straw +45% napier leftover; T_1= 5% rumen content + 5% molasses + 50% rice straw +40% napier leftover; T_2= 10% rumen content+ 5% molasses +50% rice straw +35% napier leftover; T_3= 15% rumen content+ 5% molasses + 50% rice straw +30% napier leftover; The amounts of all of the above ingredients were measured on DM basis.

Preparation of silage

The napier leftovers and rice straw were chopped to a size of 4-5 cm in length. Then the silage was prepared by mixing chopped napier leftovers, straws, with fresh rumen content, and molasses according to the above treatments. For proper mixing, rumen content and molasses were mixed first, then finally mixed with napier leftovers and chopped straws. When napier leftovers and straws were thoroughly mixed with rumen content and molasses, these were kept into the air-tight plastic containers which were previously marked according to the treatments. Finally, plastic containers were placed in a room for 28 days for successful ensiling.

Unloading silage and organoleptic test

Silage samples were collected at 0, 14, 21, and 28 days to observe how many days were required to obtain good silage. Texture (hardness), color, and smell of samples were recorded. Acceptability of silages by cattle was also observed to determine palatability.

Proximate analysis of silage

The silage samples were mixed thoroughly to determine pH by a digital pH meter and dry matter in an air-dry oven at 105°C, respectively. The dry samples were subjected to proximate analysis for crude fiber (CF), crude protein (CP) ether extract (EE), and Ash, following the methods of AOAC (2004) at Animal Science laboratory, Bangladesh Agricultural University, Mymensingh-2202. The metabolizable energy (ME) and in *vitro* organic matter digestibility (OMD) of silage were ascertained following a method narrated by Menke et al. (1979). Organic matter digestibility (%) and metabolizable energy (MJ/kg DM) contents were calculated according to the following equations by Menke and Steingass (1988).

$$IVDOM = 16.49+0.9024\,GP+0.0492CP+0.0387TA$$
$$ME = 2.20+0.1357GP+0.0057CP+0.0002859EE2$$

Where, IVOMD= *In vitro* organic matter digestibility (%), ME = Metabolizable energy (MJ/kg DM), GP = Gas production expressed in ml per 200 mg DM, CP = Crude protein (g/kg DM), TA= Total ash (g/kg DM), EE = Ether extract (g/Kg DM).

Statistical analysis

SAS Statistical Discovery Software, NC, USA, was used to analyze data at a 5% significance level and the differences among the mean values of treatments were determined by Duncan's Multiple Range Test (DMRT). The proposed model for the experiment was:

Yijk = μ + Ai + Bj + (AB) ij + εijk i=1….a; j=1…b; k=1…n

Where; Yijk= Observation k in level i of factor A and level j of factor B; μ= the overall mean; Ai= the effect of level i of factor A; Bj= the effect of level j of factor B.

RESULTS AND DISCUSSION

Physical characteristics and pH of silage

The physical characteristics of silages of T_0, T_1, T_2, and T_3 treatment at different times (0, 18, 21, and 28 days) are shown in Table 2. After 28 days of the ensiling period, the color of different treatments (T_0, T_1, T_2, and T_3) was brown, light brown, and brown. The silage color was turned deeper with increasing the rumen content level. Controlled treatment (T_0) remained hard but T_1, T_2, and T_3 became softer after ensiling 28 days. The propagation of fungus and mold was not noticeable in rumen content treated straw but some were observed in controlled treatment.

The pH of silage is shown in Figure 1. The differences ($p<0.05$) were observed among the treatments. T_0 treatment had the highest pH value followed by T_1, T_2, and T_3 due to the successive addition of rumen content.

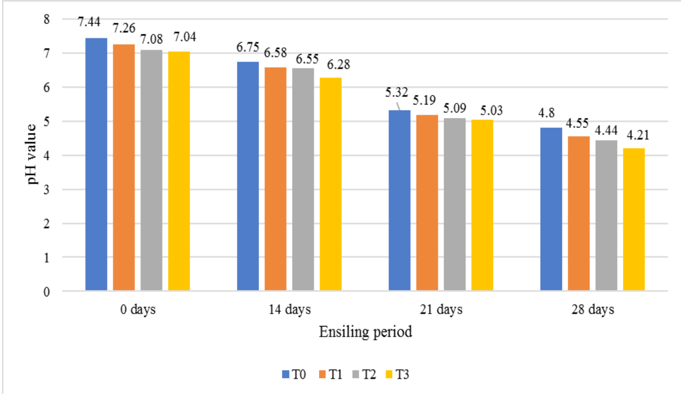

Figure 1: pH values of silages at different periods.

Chemical composition of silage

Dry matter

Table 3 shows the dry matter of silages at different times. Dry Matter (DM) (g/100g) of silages was declined ($p<0.05$) due to the enhancement of ensiling period and rumen content. The maximum DM was achieved in T_0 followed by T_1, T_2, and T_3.

Crude protein

Table 4 shows the crude protein (CP) of silages at different times. The maximum CP was discovered in T_3 (5.95%) and the minimum was in T_0 (4.42%). The CP amount of silages differed ($p<0.05$) due to the successive addition of rumen content in the ensiling period.

Crude fiber

Table 5 shows the crude fiber (CF) of silages at different times. The CF was comparatively higher (29.4%) in T_0 than in T_1 (28.9%), T_2 (28.2%), and T_3 (26.9%) which were treated with rumen content. The values were decreased ($p<0.05$) with the subsequent inclusion of rumen content in rice straw.

Ether extract

Table 6 represents the ether extract (EF) of silages at different times. The treatments (T_0, T_1, T_2, and T_3) showed differences ($p<0.05$) among them. The EE of silages was slowly reduced from 2.18% to 1.56% after an ensiling period of 28 days.

ASH

The ash of silages at different times is represented in Table 7. The ash of silages was declined ($p<0.05$) due to increasing rumen content in rice straw. The ash was the highest in T_0 (13.8%) followed by T_1 (12.9%), T_2 (12.9%), and T_3 (12.3%) at 28 days of ensiling period.

Table 2: Physical quality of silage at different ensiling periods.

Properties	Observation	Treatment			
		T_0	T_1	T_2	T_3
Color	0 Days	Straw	Straw	Light brown	Brown
	18 Days	Straw	Light brown	Dark brown	Brown
	21 Days	Light brown	Brown	Brown	Brown
	28 Days	Light brown	Brown	Brown	Brown
Smell	0 Days	sample smell	sample smell	sample smell	sample smell
	18 Days	Light vinegary	Light vinegary	Vinegary	Vinegary
	21 Days	Light vinegary	Vinegary	Vinegary	Vinegary
	28 Days	Vinegary	Vinegary	Vinegary	Vinegary
Softness	0 Days	Hard	Hard	Hard	Hard
	14 Days	Hard	Hard	Soft	Soft
	21 days	semi-soft	Soft	Soft	Soft
	28 Days	Soft	Soft	Soft	Soft
Fungus and mold	0 Days	Absent	Absent	Absent	Absent
	14 Days	Absent	Absent	Absent	Absent
	21 Days	Absent	Absent	Absent	Absent
	28 Days	Present	Absent	Absent	Absent

T_0 = 0% rumen content + 5% molasses + 50% rice straw + 45% Napier leftover, T_1 = 5% rumen content + 5% molasses + 50% rice straw + 40% Napier leftover, T_2 = 10% rumen content + 5% molasses +50% rice straw + 35% Napier leftover, T_3 = 15% rumen content + 5% molasses + 50% rice straw+ 30% Napier leftover.

Table 3: Effect of treatments and ensiling time on Dry matter of silage.

Ensiling days (D)	Treatments (T)				Mean	SEM
	T_0	T_1	T_2	T_3		
0	37.8	35.6	34.4	33.3	35.2^a	0.96
14	34.4	32.6	32.3	32.1	32.8^b	0.53
21	32.3	31.3	31.7	31.4	31.7^c	0.22
28	31.3	30.2	30.6	30.1	30.5^d	0.27
Mean	33.9^a	32.5^b	32.3^b	31.7^c		
SEM	1.44	1.17	0.80	0.67		

*Means with different superscripts within row and column are different at *$p<0.05$*. T_0 = 0% rumen content+5% molasses+50% rice straw+45% Napier leftover, T_1= 5% rumen content+5% molasses+50% rice straw+40% Napier leftover, T_2= 10% rumen content+5% molasses+50% rice straw+35% Napier leftover, T_3= 15% rumen content+5% molasses+50% rice straw+30% Napier leftover.

Table 4: Effect of treatments and ensiling time on crude protein of silage.

Ensiling days (D)	Treatments (T)				Mean	SEM
	T_0	T_1	T_2	T_3		
0	4.33	4.52	5.18	5.55	4.90^d	0.28
14	4.39	4.78	5.49	5.85	5.13^c	0.33
21	4.41	4.89	5.60	6.18	5.27^b	0.39
28	4.53	5.21	5.73	6.40	5.47^a	0.40
Mean	4.42^d	4.85^c	5.50^b	5.95^a		
SEM	0.04	0.14	0.12	0.19		

*Means with different superscripts within row and column are different ($p<0.05$). T_0 = 0% rumen content + 5% molasses + 50% rice straw + 45% Napier leftover, T_1= 5% rumen content + 5% molasses + 50% rice straw + 40% Napier leftover, T_2= 10% rumen content + 5% molasses +50% rice straw + 35% Napier leftover, T_3= 15% rumen content + 5% molasses + 50% rice straw+ 30% Napier leftover.

Table 5: Effect of treatments and ensiling time on crude fiber of silage.

Ensiling days (D)	Treatments (T)				Mean	SEM
	T_0	T_1	T_2	T_3		
0	31.2	31.0	30.4	29.2	30.5^a	0.45
14	30.1	29.9	29.1	27.2	29.1^b	0.66
21	28.7	28.0	27.1	26.2	27.5^c	0.54
28	27.7	26.8	26.1	24.9	26.4^d	0.59
Mean	29.4^a	28.9^b	28.2^c	26.9^d		
SEM	0.77	0.94	0.97	0.91		

*Means with different superscripts within row and column are different ($p<0.05$). T_0 = 0% rumen content + 5% molasses + 50% rice straw + 45% Napier leftover, T_1= 5% rumen content + 5% molasses + 50% rice straw + 40% Napier leftover, T_2= 10% rumen content + 5% molasses +50% rice straw + 35% Napier leftover, T_3= 15% rumen content + 5% molasses + 50% rice straw+ 30% Napier leftover.

Table 6: Effect of treatments and ensiling time on ether extract of silage.

Ensiling days (D)	Treatments (T)				Mean	SEM
	T_0	T_1	T_2	T_3		
0	2.56	2.37	2.00	1.80	2.18^a	0.17
14	2.43	2.20	1.84	1.67	2.03^b	0.17
21	2.41	2.06	1.67	1.46	1.90^c	0.21
28	1.79	1.69	1.45	1.30	1.56^d	0.11
Mean	2.30^a	2.08^b	1.74^c	1.56^d		
SEM	0.17	0.14	0.12	0.11		

*Means with different superscripts within row and column are different ($p<0.05$). T_0 = 0% rumen content+5% molasses+50% rice straw+45% Napier leftover, T_1= 5% rumen content+5% molasses+50% rice straw + 40% Napier leftover, T_2= 10% rumen content+5% molasses+50% rice straw+35% Napier leftover, T_3= 15% rumen content+5% molasses+50% rice straw+30% Napier leftover.

Table 7: Effect of treatments and ensiling time on Ash of silage.

Ensiling Days (D)	Treatments (T)				Mean	SEM
	T_0	T_1	T_2	T_3		
0	15.1	14.5	14.5	14.3	14.6^a	0.17
14	14.2	13.3	13.3	12.7	13.4^b	0.31
21	13.2	12.5	12.4	11.8	12.5^c	0.29
28	12.6	11.6	11.3	10.3	11.5^d	0.47
Mean	13.8^a	12.9^b	12.9^b	12.3^c		
SEM	0.55	0.62	0.68	0.84		

*Means with different superscripts within row and column are different (*p<0.05*). T_0 = 0% rumen content + 5% molasses + 50% rice straw + 45% Napier leftover, T_1= 5% rumen content + 5% molasses + 50% rice straw + 40% Napier leftover, T_2= 10% rumen content + 5% molasses +50% rice straw + 35% Napier leftover, T_3= 15% rumen content + 5% molasses + 50% rice straw+ 30% Napier leftover.

In-*vitro* organic matter digestibility (IVOMD)

The IVOMD of silages at different times is represented in Table 8. The OMD improved (*p<0.05*) with the successive increase of rumen content and the extreme value of OMD was observed in T_3 (55.3%).

Table 8: Effect of treatments and ensiling time on organic matter digestibility (OMD) of silage.

Ensiling Days (D)	Treatments (T)				Mean	SEM
	T_0	T_1	T_2	T_3		
0	52.6	53.0	53.5	56.0	53.8^b	0.76
14	52.9	53.5	53.7	54.9	53.7^b	0.42
21	53.2	54.4	54.7	54.9	54.3^a	0.38
28	53.4	54.6	55.3	55.2	54.6^a	0.44
Mean	53.0^c	53.9^b	54.3^b	55.3^a		
SEM	0.18	0.38	0.42	0.26		

*Means with different superscripts within row and column are different (*p<0.05*). T_0 = 0% rumen content + 5% molasses + 50% rice straw + 45% Napier leftover, T_1= 5% rumen content + 5% molasses + 50% rice straw + 40% Napier leftover, T_2= 10% rumen content + 5% molasses +50% rice straw + 35% Napier leftover, T_3= 15% rumen content + 5% molasses + 50% rice straw+ 30% Napier leftover.

Metabolizable energy (ME)

The ME of silages at different times is represented in Table 9. The ME of silages was enhanced (*p<0.05*) with the successive addition of rumen content. The ME value of silages was the highest in T_3 (7.89%) and T_0 had the lowest value (7.61%).

To assess the quality of silage, the determination of organoleptic characteristics is essential (Kung et al., 2018). One of the most important parameters for determining silage quality is color. The color in the silage changes from light green to light brown depending on the source of feed materials but black colors are not desirable (Toruk and Gonulol, 2011). During the ensiling process, silage looks a dry appearance and a brownish coloration (Kung et al., 2018). Similar results were observed in the experiment where the color changes from light brown to brown color.

Table 9: Effect of treatments and ensiling time on metabolizable energy (ME) of silage.

Ensiling days (D)	Treatments (T)				Mean	SEM
	T_0	T_1	T_2	T_3		
0	7.54	7.60	7.68	7.81	7.66^d	0.06
14	7.59	7.68	7.71	7.89	7.72^c	0.06
21	7.64	7.78	7.87	7.90	7.80^b	0.06
28	7.68	7.86	7.97	7.96	7.87^a	0.07
Mean	7.61^d	7.73^c	7.81^b	7.89^a		
SEM	0.03	0.06	0.07	0.03		

*Means with different superscripts within row and column are different (*p<0.05*). T_0 = 0% rumen content + 5% molasses + 50% rice straw + 45% Napier leftover, T_1= 5% rumen content + 5% molasses + 50% rice straw + 40% Napier leftover, T_2= 10% rumen content + 5% molasses +50% rice straw + 35% Napier leftover, T_3= 15% rumen content + 5% molasses + 50% rice straw+ 30% Napier leftover

During the ensiling process, proteins and sugars bind together at high temperatures. The trapped oxygen in the silage mass stimulates metabolic activity and plant respiration of aerobic microorganisms and produces heat. At this process, the odor is more slightly vinegary which is desirable (Kung et al., 2018). In the experiment, molasses and rumen content were the sources of sugar and protein and they were involved in the production of pleasant odors like vinegary smells stated by (Kung et al., 2018). Aerobically unstable silages can also smell musty or moldy and can show visible fungus or mold growth. Moldy silage should be disposed of as it could be contaminated with mycotoxins (Kung et al., 2018). In different treatments, the study showed no fungal or mold growth except T_0 due to the proper sealing of the plastic containers and the maintenance of anaerobic conditions.

The pH of all treatments after 28 days ensiling period was the same at the pH ranges of silages between 4.3-4.7 mentioned by Borreani et al. (2018). During ensiling, lactic acid, which is produced by lactic acid bacteria (LAB), is usually the acid found in the highest concentration in silages and contributes the most to the decline in pH (Kung et al., 2018). Rumen contents result mainly from the anaerobic fermentation and production of high-quality microbial protein, volatile fatty acids, and significant amounts of microbial storage carbohydrates, lipids, minerals, and ruminal microorganisms, especially lactic acid bacteria (Osman et al., 2015; Cherdthong, 2020; Guo et al., 2020). As rumen content was used in the experiment, the ruminal lactic acid bacteria in the rumen help to lower the pH of the silages.

In the experiment, DM was gradually decreased with increasing ensiling time. A similar result was found by Man and Wiktorson (2003) where the DM was reduced from 28.0% to 26.4%, with increasing the ensiling time being increased from 2 to 4 months. In addition, losses of DM can result from runoff, oxidation, and the loss of volatile organic compounds (Borreani et al., 2018). In this experiment, crude protein and organic matter digestibility were improved following the ensiling period of 28 days. Cherdthong (2020) pointed that ensiling the rumen content improved the protein and organic matter digestibility for rumen microbes, although the researchers further stated that the protein in the material could be converted to NH_3 if the process exceeded 4 weeks. Moreover, De Boever et al. (2013) reported that in *vitro* organic matter digestibility of ensiled grass was improved from 82.3% to 83.9% after 150 days of ensiling, respectively.

The ash and ether extract were declined with increasing ensiling period and rumen content. These changes are due to the use of ash and ether extract for microbial growth during the ensiling period. Similar results were observed in Gerlach et al. (2013). On the other hand, the metabolizable energy was improved with increasing the rumen content and ensiling period. The improved ME is desirable because rumen microorganisms are present in silage preparation that utilize organic matters and improve the digestibility of feedstuff (Cherdthong, 2020).

CONCLUSIONS AND RECOMMENDATIONS

Using the rumen content in silage materials (rice straw, and napier leftovers) can enhance the physical properties, nutritional quality, and preservation capacity of rice straw. Rumen content treated (T_1, T_2, and T_3) rice straw and napier leftovers showed better nutritional properties. By comparing physical characteristics, and nutritive values among (T_1, T_2, and T_3), the T_3 was the best. Further investigation is required for an *in-vivo* feeding trial between T_1 and T_2 to justify the findings. Therefore, we can conclude that the addition of rumen content and molasses with rice straw, and napier leftover improves the quality of feed as well as may solve the waste disposal problems in the slaughterhouse.

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NOVELTY STATEMENT

The utilization of agricultural by-products and slaughterhouse wastes is a crucial matter in Bangladesh. The study was designed to focus on the conversion of these wastes into valuable products as ruminant feed.

AUTHOR'S CONTRIBUTION

All authors contributed equally.

Conflict of interest

The authors have declared no conflict of interest.

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