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Investigate the Effects of Wastes Valorization of Corn Straw an Alternative Feed for Fattening Calves by Treated of Ammonia Gas

Research Article

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ABSTRACT

The purpose of this study was to investigate the effects of valorizing corn straw as an alternative feed for fattening calves by treating it with ammonia gas. Different levels of ammonia gas (AG) (0, 2, 3, and 4%) were injected into bags containing moistened corn straw. The plastic bags were stored at 20-25 °C for one month. The results showed that corn straw processed with 4% AG, compared to other experimental treatments, increased the amount of protein (P<0.05). Corn straw treated with 3% AG increased the amount of ether extract compared to the untreated group (P<0.05). Corn straw processed with 3% and 4% AG reduced acid detergent fiber (ADF) (P<0.05). Corn straw treated with 4% AG reduced neutral detergent fiber (NDF) compared to the control group. Additionally, the NDF of corn straw was reduced by using a 3% level of AG (P<0.05). Corn straw treated with 4% AG significantly improved the digestibility of organic matter (% DOM), digestibility of organic matter in dry matter (% DOMD), and metabolizable energy (ME) (P<0.05). Corn straw treated with 4% AG increased gas production at 6, 12, 48, and 72 hours of incubation, but no significant difference was observed at 24 and 36 hours of incubation. Nutritional parameters results of gas production (digestibility of organic matter (OMD), ME, and short-chain fatty acids (SCFA) were not affected by processing with ammonia gas. The highest feed intake was recorded with processed corn straw at 9.108 kg, while the feed conversion ratio remained stable, indicating no significant improvement in weight gain efficiency. Total feed costs were lowest for calves without corn straw at $176.320, with minimal increases for unprocessed and processed corn straw options, highlighting the economic considerations of incorporating corn straw into feeding strategies. In general, it can be concluded that treating corn straw with 4% ammonia gas improves its nutritional value by enhancing protein content and digestibility. Despite the increased feed intake, feed conversion efficiency remained unchanged, suggesting economic advantages in calf feeding strategies.

KEY WORDS ammonia gas, biomass, corn grain straw, digestibility.

INTRODUCTION

The uncontrolled rise in the production of organic wastes, including agricultural wastes, poses an unprecedented threat to the environment in today's world. Therefore, to tackle this challenge and prevent further damage to the environment, many countries have opted to implement management strategies such as organic waste reduction (Khalid *et* al. 2011). The lack of proper nutritional insight into many common feeds has caused a great deal of waste (Behgar, 2009). Agricultural by-products contain high lignocellulosic material, a main energy source with a considerable level of hydrocarbons and a small number of minerals and vitamins. Straw obtained from cereals, legumes, and wood wastes are the most important lignocellulosic compounds that fall into the category of uncommon feeds in livestock diets. These products are composed of polysaccharide compounds, most of which are cellulose and hemicellulose. In plants, cellulose is covered with lignin and hemicellulose, which make enzymes difficult to access (Yang *et al.* 2012). However, the utility of cereal straws in ruminant diets may be limited by their low crude protein content and high levels of cellulose, hemicellulose, and lignin (Mahesh and Madhu, 2014; Singh *et al.* 2016). Simmons *et al.* (2010) stated that the presence of lignin in cereal straws inhibits the hydrolysis process and consequently reduces digestibility. Lignocellulosic materials are resistant to the process of decomposition in the rumen, which affects their digestion, thus preventing access to a wide range of energy sources (Sahoo *et al.* 2002).

One of the valuable agricultural resources produced in large amounts worldwide is grain corn straw. Farmers often cause environmental pollution by incinerating or improperly disposing of this valuable resource (Feng *et al.* 2018). Corn straw has a higher nutrient content and is more digestible than most other straws. The crude protein (CP) content in this substance is 60 g/kg DM, and its ME is about 9 MJ/kg DM. Corn straw includes straw, leaves, and other plant derivatives. Reports indicate that the nutritional value of grain corn straw can be improved through chemical processing methods (Anbarinejad, 2018). Various strategies have been utilized to enhance the utilization of cereal straws by ruminants (Nguyen *et al.* 2012). Treating low-quality feeds with ammonia has been found to be an effective and affordable strategy to improve their feed value (Sarnklong *et al.* 2010; Beigh *et al.* 2017). Sarnklong *et al.* (2010) reported that ammonia treatment has the potential to hydrolyze the cell wall of roughages, thereby reducing the fiber content. Several studies have recorded that ammonia treatment of cereal straws increased intake as well as digestibility (Cömert *et al.* 2015). Sadeghi *et al.* (2015) reported that the ammonia level used affected the processing quality more positively compared to the gaseous form of ammonia, which could be attributed to greater retention of liquid ammonia compared to its gaseous form. However, the high retention rate of this chemical compound is not suitable for animal use. Additionally, from a commercial perspective, it is almost impossible to process large quantities of straw using the liquid form. Therefore, these studies suggested the use of the gaseous form of ammonia. Due to the importance of using agricultural by-products and the potential for improving this type of product through chemical processing, especially with ammonia gas, and the lack of sufficient evidence about the nutritional value of corn straw, it is often not considered by dairy farmers and is not used properly in animal nutrition. Therefore, this study was designed and conducted to investigate the effects of waste valorization of corn straw by treatment with AG on fattening calves.

MATERIALS AND METHODS

Materials

The current study was conducted at Moghan Agro-industry and Animal Husbandry Company. Closed plastic bags were used to treat corn straws with AG and to evaluate their effects on nutritional value and digestibility. The collected samples were dried and ground in the experimental environment. For this purpose, 4 kg of corn straw was poured into the silo, and the doors were closed tightly. Then, four levels of AG (0, 2, 3, and 4) were injected into four plastic bags. Before processing, the moisture content of the corn straw was 25 percent. Straw processed with different levels of AG was stored at 20 to 25 °C for one month. After this period, the processed straws were subjected to laboratory analysis after 4 days of exposure to fresh air.

Chemical composition, dry and organic matter digestibility

Dry matter (DM), crude protein (CP), crude fat, and ash of samples of corn straw and feed ration, were determined by the Association of official agricultural chemists (AOAC, 1990). Also, the neutral detergent fiber (NDF) and acid detergent fiber (ADF) of the samples were determined by the method of Van Soest *et al.* (1991).

In vitro digestibility was determined by Holden (1999) modified Tilly and Terry method. In this method, a nylon bag was used instead of filtration, and a daisy incubator (rumen simulator) was used instead of a hot water bath. A sample of ground corn straw was poured into a nylon bag and the bag was closed with a plastic sewing machine. Then, the digestibility of organic matter and organic matter in the dry matter was calculated based on the following equations:

$$DMD(\%)= ((\text{nutrient in}–\text{nutrient out})/(\text{nutrient in})) \times 100 \quad (1)$$

$$ME= 0.0157 \times DOMD \quad (2)$$

$$DOMD= OM \times ODM \quad (3)$$

Where:
ME: metabolizable energy in terms of MJ/kg.

DOMD: digestibility of organic matter in the dry matter calculated by using Holden's (1999) modified Tilly and

Terry method.
OMD: digestibility of organic matter.
OM: organic matter.

Biogas production

Gas production was measured by Menke *et al.* (1979) method. After grinding samples with a 1 mm sieve, 200 mg of each of the four samples was poured into 100 ml special scaled glass syringes. Ruminal fluid was collected about one hour before feeding in the morning from 2 sheep with fistulas, fed twice a day at regular intervals with a diet containing 700 grams (alfalfa, corn silage), 300 grams per kilogram of concentrate mixture (barley, cottonseed meal, bran, and supplement), and filtrated with a special 4-layer cloth and remitted to a laboratory in a flask containing carbon dioxide. The filtrated and fresh liquid and buffer was prepared according to the method of Menke *et al.* (1979) and the corrected method of Menke and Steinggass (1988) were mixed in ratios of 1 (ruminal fluid) to 2 (buffer), while the flow of carbon dioxide continued into the mixture. 30 ml of the mixture of ruminal fluid and culture medium was removed by using the serological pipettes and poured into each syringe containing the sample. The syringes were then placed at 39 ˚C which rotated at the rate of one revolution per minute (rpm) to continuously mix the contents of the syringes. 30 mL of a combination of ruminal fluid and artificial saliva were used to eliminate the error caused by the gas produced by the action of microorganisms on the food in the ruminal fluid from control samples. A syringe was used for all three replications. The position of the piston and the amount of gas produced were read and recorded at times 2, 4, 6, 8, 12, 24, 48, 72, and 96 hours after the syringes were placed in the incubator. Based on the weight of the feed sample at any time, the amount of gas produced was adjusted by using the following equation:

$$V= ((200\times(V_t–V_b)) / W \quad (4)$$

Where:
V: volume of the corrected gas (mm) per 200 mg of dry matter of feed sample.
Vt: volume of gas produced in syringes without feed sample.
Vb: volume of gas produced in syringes without feed sample (mL).
W: weight of feed material (mg).

The amount of short-chain fatty acids (SCFA) (Menke and Steinggass, 1988; Blümmel and Orskov, 1999), digestibility of organic matter (DOM) (Menke *et al.* 1979), and ME (Menke *et al.* 1979; Blümmel and Orskov, 1999) were calculated using the following equations.

ME (MJ/kg DM)= 1.06 + 0.1570GP + 0.0084CP + 0.0220EE - 0.0081CA (5)

DOM (DM %)= 9 + 0.99GP + 0.0595CP + 0.018CA (6)

SCFA (mmol/200 mg DM)= 0.0222GP - 0.00425 (7)

Growth performance of fattening calves

After reviewing the laboratory results, 4% AG levels were selected. 24 male Holstein calves weighing on average 250 kg were used in a totally randomized design with 3 experimental diets and 8 replications to evaluate the influence of corn straw processing on the performance of fattening male calves. Treatments included the following: 1) Experimental diet without grain corn straw, 2) Experimental diet + unprocessed corn straw, and 3) Experimental diet + corn straw processed with 4% AG. Experimental diets were adjusted by using standard beef requirements Table 1 (NRC, 1996). The duration of this study was 60 days. Body weight (BW), daily weight gain (DWG), and feed conversion ratio (FCR) were measured during this period.

Economic estimate

For the financial analysis, the cost of one kilogram of feed was assumed to be $0.033. This cost was multiplied by the daily feed intake for each treatment to determine the daily feed cost. Subsequently, considering a fattening period of 60 days for the calves, the daily feed cost for each treatment was multiplied by 60 to calculate the total feed cost over the entire fattening period.

Statistical analysis

The data obtained from gas production in the form of a completely randomized design by repeated measurement method, and Holden digestibility in the form of a completely randomized design were analyzed by using SAS (2004) software and Mixed procedure. The model used in this procedure was a mixed model including the effect of treatment (feedstuff), the effect of incubation time and the interaction between treatment and time as fixed effects, and the effect of the four repetition within each treatment as a random effect. The means are displayed as minimum squares (SMEAN) with standard error. The statistical models are as following:

$$Y_{ijk}= \mu + \alpha_i + \beta_{ij} + e_{ki} + e_{ijk} \quad (8)$$

$$Y_{(i)}= \mu + \alpha_{(i)} + e_{(ij)} \quad (9)$$

Where:
μ: average.
αi: effect of i treatment.

βij: interaction between treatment and time, random error resulting from repetition within the treatment.
$e_{(ij)}$, e_{ki} and e_{ijk}: residual error.

RESULTS AND DISCUSSION

Results of chemical composition are presented in Table 2. Compared to the unprocessed treatment, all three levels of AG increased the crude protein of corn straw (P<0.05). Among these levels, the 4% level had the greatest impact. The no additive control and corn straw + 3%NH_3 treatments had significantly (P<0.05) lowest and the highest level of ether extract (EE), respectively. The amount of ash of corn straw was not affected by experimental treatments. The processing of corn straw with different levels of AG reduced NDF compared to the no additive control treatment (P<0.05).

The results of the processing of grain corn straw with different levels of AG on the digestibility *in vitro* by the modified Tilly and Terry method (Holden, 1999) are shown in Table 3. The DOM of the corn straw +4%NH_3 treatment was higher than the other treatments (P<0.05). Also, processing of corn straw with 4% AG had higher content of DOMD and ME compared to the no additive control.

Results of gas production *in vitro* are presented in Table 4. As can be seen, the amount of gas produced by corn straw during 3 incubations was not affected by AG processing (P>0.05). Processing of corn straw with 4% AG had increased the amount of gas produced at times 6, 12, 48, and 72 hours than the no additive control treatment (P<0.05). However, at 24 and 36 hours of incubation, the amount of gas produced was not affected by different levels of ammonia gas. As seen in Table 3 treated corn straw with different levels of AG had no significant effect on the OMD, ME, and SCFA. But numerically, processing corn straw with 2% AG did not significantly increase OMD, ME, and SCFA compared to other experimental treatments.

As shown in Table 6, the use of unprocessed corn straw had the lowest final weight and daily weight gain compared to other groups. Calves fed with processed straw gained more body weight compared with unprocessed corn straw group; but no significant effect was observed between treatments (P>0.05). Supplementing the diet of fattening calves with corn straw processed with 4% AG increased the feed consumption insignificantly compared to other experimental treatments. Feed intake also increased with the use of corn straw. The highest intake was observed with processed corn straw at 9.108 kg, compared to 8.816 kg without corn straw (P<0.05). Feed Conversion Ratio (FCR) which indicates the efficiency of converting feed into weight gain, was relatively stable, varying from 6.08 for non-straw diets to 6.60 for processed corn straw.

This suggests that while feed intake increased, the efficiency of weight gain did not significantly improve with the addition of corn straw. The total feed cost for the group not receiving corn straw was $176.320. This option represents the baseline feeding strategy with the lowest overall cost. The inclusion of unprocessed corn straw resulted in a total feed cost of $177.580, indicating a marginal increase of $1.260 compared to the group without corn straw. This suggests that while unprocessed corn straw can be a viable feed option, it does not significantly raise costs. The highest total feed cost was observed for calves fed with processed corn straw, totaling $182.160. This represents an increase of $5.580 compared to the unprocessed option and $5.840 compared to the non-straw diet.

In the current study, we showed that treatment of corn straw with 3 and 4% of AG reduced NDF and ADF content. In contrast, the protein content of corn straw was increased by the processing of all three levels of AG (Table 2). A study reported that processing semi-dried corn straw with 5% sodium hydroxide reduced the amount of NDF by 14%. It also solubilized 35% of hemicellulose, 8.7% of cellulose, and 11.3 of lignin (Jami *et al.* 2014). Yalchi *et al.* (2010) investigated the effects of ammonia and urea on grain corn residue and stated that using of urea and ammonia increased the amount of protein and ammonia nitrogen. These researchers also stated that NDF of grain corn decreased with the processing of 3 and 4.5% ammonia and urea. In this study, the amount of lignin tended to decrease due to processing with ammonia and urea, but no significant difference was observed between the treatments. Results of our study are consistent with the results of Danesh (2012) and Sadeghi *et al.* (2015) suggesting that the use of 4% AG reduced the amount of NDF and ADF while the amount of crude protein of corn straw was significantly increased by processing with 4% of ammonia gas. Oji *et al.* (2007) investigated the processing of corn residues with urea and anhydrous ammonia and found that processing with 3% urea and ammonia increased the amount of protein and also improved the digestibility of NDF, ADF, and OM compared to the control group. The report also states that processing straw with AG increased its digestibility by about 10 to 15% and processing wheat straw with 3% AG increased the digestibility of hemicellulose, NDF, and ADF by 39%, 59%, and 150%, respectively (Prassad, 1993). Another study, Schneider and Flachowsky (1990) reported that processing straw with ammonia reduced the amount of NDF, lignin, and hemicellulose but did not have a significant effect on ADF. Saenger *et al.* (1983) argued that the use of anhydrous ammonia increases the amount of protein and decreases the NDF and ADF. Hemicellulose is further reduced among the components of the cell wall, which indicates that it is dissolved by processing.

Table 1 Feed items and chemical composition of the experimental diets (g/kg DM)

Item	Control	Unprocessed corn straw	Corn straw processed with 4% of NH_3
Hay	100.0	100.0	100.0
Corn silage	101.0	101.0	101.0
Wheat bran	24.0	24.0	24.0
Corn straw	0.0	104.0	104.0
Soybean meal	100.0	100.0	100.0
Barley	648.0	544.0	544.0
Salt	4.0	4.0	4.0
Sodium bicarbonate	7.0	7.0	7.0
Calcium carbonate	9.0	9.0	9.0
Mineral and vitamin mix	7.0	7.0	7.0
Chemical composition			
Net energy maintenance (Mcal/kg)	1.70	1.70	1.72
Net energy growth (Mcal/kg)	1.09	1.09	1.09
Crude protein g/kg DM	150.0	142.8	157.8
Neutral detergent fiber, g/kg DM	320.0	324.1	302.7
Acid detergent fiber g/kg DM	160.0	166.6	148.5

Table 2 Effects of processing corn straw with ammonia gas (AG) on the chemical composition of corn straw

Item	ADF	NDF	Ash	EE	CP
Corn straw + 0% NH_3	34.49^{a}	63.46^{a}	7.85	1.88^{b}	4.82^{c}
Corn straw + 2% NH_3	30.80^{ab}	59.40^{b}	7.49	2.01^{ab}	5.50^{b}
Corn straw + 3% NH_3	29.20^{b}	55.93^{bc}	7.09	2.48^{a}	6.10^{ab}
Corn straw + 4% NH_3	28.32^{b}	54.33^{c}	7.78	2.45^{ab}	7.36^{a}
SEM	1.45	1.07	0.45	0.07	0.28
P-value	0.05	1.45	0.64	0.05	0.01

ADF: acid detergent fiber (DM %); NDF: neutral detergent fiber (DM %); Ash: ash (DM %); EE: crude fat (DM %) and CP: crude protein (DM %).
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

The loss of the acetyl group and the increase of radical carboxyl due to the release of ester bonds of uranic acids can be mentioned among the reasons for the changes in the hemicellulose fraction (Graham *et al.* 1985).

In our study, corn straw treated with 4% AG improved DOM, DOMD and ME compared to the control group (Table 3). Similarly, Yalchi (2010) reported that the processing of corn residue with 1.5 % urea and 3% ammonia improved the digestibility of DM and OM *in vitro*. Oji *et al.* (2007) reported that corn residue processing with aqueous ammonia and urea improved the digestibility of DM, NDF, ADF and OM, but no significant difference was observed between aqueous ammonia and urea treatments. Anbarinejad (2018) investigated the influence of rumen microorganisms on *in vitro* digestibility of corn straw and showed that processing corn straw with rumen microorganisms does not improve digestibility. In a study, it was reported that corn straw treated with calcium oxide (CaO) increased the degradability of DM, NDF, and ADF (Shi *et al.* 2022). Taiwo *et al.* (1992) and Flachowsky *et al.* (1996) found that treating grain corn residues with urea and anhydrous ammonia enhanced the digestibility of DM, OM, NDF, and ADF.

Selim *et al.* (2004) showed that processing straw with ammonia increases the sensitivity and vulnerability of the cell wall in addition to reducing the phenolic acid content of the feed, which changes and facilitates the attachment of bacteria to the cell wall.

The gas produced in corn Straw +4%NH_3 treatment after 6, 12, 48 and 72 h time incubation was higher compared to the control treatment (Table 4). Sommart *et al.* (2000) stated that the amount of gas production is highly correlated with the digestibility of DM and OM. In this regard, Sadeghi *et al.* (2012) investigated treated straw with gas and ammonia liquid on gas production and showed that the use of 6% of ammonia liquid had the highest amount of gas production during 24 incubation compared to unprocessed straw.

Babayemi (2006) stated that the decrease in the amount of gas produced in unprocessed straw is attributed to an increase in the amount of cell wall compounds and a decrease in NFC and this could lead to a decrease in microbial activity during inconsistent conditions in the incubation time process. Ammonia increases digestion by increasing the fragility rate of the cell wall.

Table 3 Effects of processing corn straw with ammonia gas (AG) on digestibility by modified Tilly and Terry method (Holden, 1999).

Item	DOM	DOMD	ME
Corn straw + 0% NH_3	46.26^{b}	44.34^{b}	7.09^{b}
Corn straw + 2% NH_3	52.20^{ab}	47.88^{ab}	7.66^{ab}
Corn straw + 3% NH_3	54.46^{b}	49.02^{ab}	7.84^{ab}
Corn straw + 4% NH_3	56.46^{a}	50.82^{a}	8.13^{a}
SEM	1.58	1.42	0.22
P-value	0.05	0.06	0.06

DOM (%): digestibility of organic matter; DOMD (%): digestibility of organic matter in dry matter and ME: metabolizable energy (MJ/kg DM).
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 4 Effects of processing corn straw with ammonia gas (AG) on the gas production of corn straw

Item	Incubation times (Hours)						
	3	6	12	24	36	48	72
Corn straw + 0% NH_3	5.66	7.66^{b}	20.00^{b}	32.00	45.33	48.33^{b}	51.33^{b}
Corn straw + 2% NH_3	5.33	8.66^{ab}	22.33^{ab}	38.33	47.33	52.33^{b}	57.00^{ab}
Corn straw + 3% NH_3	6.66	9.00^{ab}	25.00^{a}	34.66	50.33	54.00^{b}	56.66^{ab}
Corn straw + 4% NH_3	6.00	10.33^{a}	27.00^{a}	37.33	51.66	60.00^{a}	61.66^{a}
SEM	0.64	0.57	1.39	1.97	2.08	1.69	1.77
P-value	0.53	0.06	0.03	0.18	0.21	0.01	0.02

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 5 Effects of processing corn straw with ammonia gas (AG) on the nutritional parameters of gas test of corn straw

Item	OMD	ME	SCFA
Corn straw + 0% NH_3	48.91	6.60	0.706
Corn straw + 2% NH_3	54.54	7.47	0.847
Corn straw + 3% NH_3	51.28	6.97	0.765
Corn straw + 4% NH_3	53.65	7.98	0.824
SEM	1.75	0.26	0.04
P-value	0.18	0.16	0.18

OMD (%): digestibility of organic matter; ME: metabolizable energy (MJ/kg DM) and SCFA: short chain fatty acids (Mmol/200 mg DM).
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 6 Effects of processing corn straw with ammonia gas (AG) on growth performance and economic efficiency of Holstein fattening calves

Item	Initial Weight (kg)	Final weight (kg)	Daily weight gain (kg)	Feed conversion ratio	Daily feed intake (kg)	Daily feed cost ($)	Total feed cost for 60d ($)
Without corn straw	273	358	1.45	6.08	8.816^{b}	2.943	176.320
Corn straw unprocessed	270	349	1.30	6.83	8.879^{b}	2.963	177.580
Corn straw processed	272	354	1.38	6.60	9.108^{a}	3.036	182.160
SEM	30.38	32.83	0.06	0.32	0.48	-	-
P-value	0.87	0.08	0.07	0.23	0.04	-	-

SEM: standard error of the means.

Liu *et al.* (2002) showed that processing rice straw increases the rate of gas production and thus increases its digestibility. These researchers stated that processing wheat straw with 3% ammonia hydroxide increased gas production *in vitro*. Increasing the amount of cell wall compounds and decreasing the amount of NFC are among the effective factors in reducing the gas produced because, at all times, incubation of cell wall compounds has a negative correlation with gas production (De Boever *et al.* 2005).

This may lead to a decrease in microbial activity during the increase of unfavorable environmental conditions in the incubation process.

Compared to the control group, corn straw processing with different levels of AG had no significant effect on DOM, SCFA and ME (Table 5). Sommart *et al.* (2000) stated that the volume of gas produced is one of the appropriate parameters to predict the digestibility, and fermentation of microbial protein synthesis from the substrate by ruminal microorganisms in the laboratory system. Blummel and Orskov (1993) showed that the volume of gas produced was highly correlated with dry matter and organic matter digestibility, feed intake, and growth rate in livestock. Menke and Steinggass (1988) also stated that there is a positive correlation between the metabolizable energy calculated from the gas production method and the protein and fat content of the feed with metabolizable energy computed *in vitro* method. Fermentation of carbohydrates produces SCFA and carbon dioxide and ammonia gas. Blummel and Orskov (1993) observed a close correlation between the gas produced by the incubation of grain straw and volatile fatty acid. Sadeghi *et al.* (2012) reported that the use of 6% AG produced higher SCFA, which is a sign of energy supply for ruminants. Also, they showed that the use of 6% AG improved the digestibility of dry matter. Al-Masri (2005) investigated the influence of sodium hydroxide and hydrobromic acid on the digestibility and gas production of wheat straw and peanut flake and reported that the use of sodium hydroxide did not impact gas production and digestibility.

Calves fed with processed corn straw had similar growth performance compared to the control group, but unprocessed corn straw had lower body weight and weight gain. The lowest FCR was for the control group (Table 6). Karimi *et al.* (2019) investigated the effects of enrichment of corn residual with urea and molasses on the performance of Turki-Ghashghaei male lambs and reported that the use of treated corn straw had no negative effect on BW, DWG and FCR of lambs. Rahman (2001) found that fattening male calves fed with wheat straw processed with urea and molasses gained more weight and consumed more dry matter compared to calves fed diets containing processed rice straw with urea and molasses. Orskov (2003) stated that the increase in fiber digestibility increases the *ad libitum* intake of feed in livestock, which in turn increases the performance of livestock. Berger *et al.* (1979) investigated the influence of maize residual on the diet of fattening calves and reported that the use of maize in the male calves improved feed efficiency by 19%. Russell *et al.* (2011) reported that the use of corn residual did not reduce growth yield compared to conventional forages. Russell *et al.* (2011) and Duckworth *et al.* (2014) investigated the effects of treated grain corn straw with calcium oxide in fattening calves and showed that the use of calcium oxide-treated grain corn straw reduced the final weight of fattening calves compared to calves fed diets without corn straw. Adebowale (1985) showed that the nutritional value of corn kernels is higher than all other parts of corn, while corn cob is the lowest, and corn pods and forage were placed between these two parts. The economic evaluation reveals that feeding Holstein fattening calves without corn straw is the most cost-efficient option, both in terms of total and daily feed costs. While the inclusion of corn straw (both unprocessed and processed) adds only a modest increase in costs, the processed option significantly elevates expenses. Therefore, producers should carefully consider the trade-offs between the costs and potential benefits of using corn straw in their feeding strategies, focusing on achieving optimal growth rates and economic returns.

CONCLUSION

In conclusion, treating corn straw with 4% ammonia gas enhances its nutritional value by increasing crude protein content and improving digestibility. Although this treatment results in higher feed intake, the overall feed conversion efficiency remains unchanged, indicating no significant improvement in weight gain efficiency. Nonetheless, using ammonia-treated corn straw can offer economic benefits in calf feeding strategies due to its enhanced nutritional value.

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