The effects of physical forms of corn and forage source on growth performance, blood parameters and ruminal fermentation of Holstein calves

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Abstract

This investigation's purpose was the evaluation the effects of physical forms of corn and forage sources on growth performance, blood parameters, and ruminal fermentation of Holstein calves. Forty-eight Holstein calves (38.2 ± 1.2 kg of BW) were used in a completely randomized design with 4 treatments and 12 replications for 65 days. The treatments were: 1) Basal diet + mashed form corn + wheat straw (MCWS), 2) Basal diet + flacked form corn + wheat straw (FCWS), 3) Basal diet + mashed form corn+ Sugarcane bagasse (MCSB) and 4) Basal diet + flacked form corn + sugarcane bagasse (FCSB). Final body weight and daily weight gain were affected significantly by the forage (F) factor whereas no effect from C (corn physical forms) and C×F interaction were observed. Skeletal growth parameters were not affected by C, F, and F×C factors. The trial factors did not affect triglyceride, urea and BHBA levels. Glucose level and urea were affected by C and F factors. At 30 and 60 days, calves fed on FCWS had the highest glucose. Also, calves fed the FCSB diet presented higher urea at 30 and 60 days. Acetic acid was affected significantly by C, F, and C×F interaction. Calves fed the MCWS diet had the maximum concentration of acetic acid. At 30 days, propionic acid was affected by C, F, and C×F interaction. Valeric acid was affected by C and F effect at 30 days. While for valeric acid no differences were observed at 60 days.

Introduction

The physical and metabolic development of the rumen facilitates the shift from the pre-ruminant phase to the adult ruminant (9, 21). Pre-weaning growth is a difficult progression that is influenced by nutritional factors, nutritional plans, and feed administration (4). Differences in grain fermentability (20, 23), grain processing (29), forage level (25), and forage kind or source (7, 23) can affect growth performance in calves. Feed processing and its physical shape affect the palatability and feed intake in suckling calves (17, 36), and consequently, the physical and metabolic growth of the rumen seems to be essential (4). Also, the processing of cereal grains along with methods used in feed manufacturing influences the ruminal and intestinal digestibility of feed and starch (14) and performance (12, 20) of both young and adult cattle.

Providing a ground starter feed along with forage is another way to inhibit the abnormal growth of the ruminal epithelium without the use of a textured or pelleted starter feed, which ultimately reduces the production cost for the dairy farming system (6). Some reports support the use of forage sources in improving the growth performance of suckling calves (7, 21). Studies have revealed that feeding forage in pre-weaning calves improves feed intake, daily weight gain, and ruminal fermentation (8, 24). Stimulation of the rumen muscle layer (23, 35) stimulates rumination

(13) and reduces behavioral problems (31). Probably in contradiction the results of forage feeding in suckling calves may be related to foraging type and quality, starch source, feed processing, and physical form of starter. The hypothesis of this study was whether the use of forage can reduce the negative effect of corn shape in dairy calves or are ineffective. Therefore, this study project was designed and implemented to explain the effect of corn grain treatment with different types of fiber sources on growth performance, blood parameters, and ruminal fermentation of Holstein calves.

Materials and Methods

Forty-eight neonatal Holstein calves (mean birth weight 38 ± 3 kg; age 1–3 days; on July and August 2018) were carefully chosen from the Peghah dairy herd to evaluate the influence of corn grain processing with different fiber sources on growth performance, blood parameters, and ruminal fermentation. Trial treatments were: 1) Basal diet + mashed form corn + wheat straw (MCWS), 2) Basal diet + flacked form corn + wheat straw (FCWS), 3) Basal diet + mashed form corn+ sugarcane bagasse (MCSB) and 4) Basal diet + flacked form corn + sugarcane bagasse (FCSB). In the first 24 hours next birth, calves were detached from their maternal cows and allotted to the experimental groups randomly from day 4 of life until the end of the experiment (days 70 of life). Calves were assigned randomly among the groups based on their age and birth weight to get similar average weight and age among the treatments. Calves were drunk 4 L of colostrum twice in the first 8 hours of birth, the rest of the colostrum was fed in 2 days according to the 10% of body weight. Milk whole for calves to intake was provided twice a day at 8:00 and 18:00 by plastic bucket and controlled to completely consuming by calves. On day 4, water and starter were offered adlibitum to the calves. Dried alfalfa was offered to the calves from day 20 of life as 10 percent of the starter diet. Investigational diets and their chemical composition are presented in Table 1.

Sampling and analysis

Chemical composition: Before chemical analysis, feed samples for crude protein, ether extract, ash (1), neutral detergent fiber, and acid detergent fiber (37) were air-dried at 60 °C and ground with a 1 mm sieve.

Table 1. The components of trial diets (starter feed) and their chemical composition (Dry matter %).

Items	Mashed corn		Flacked corn	
	WS	SB	WS	SB
Mashed form corn	62.4	62.4	-	-
Flacked form corn	-	-	62	62
Soybean meal	27.6	27.6	28	28
Wheat straw	5	-	5	-
Sugarcane bagasse	-	5	-	5
Pre-mixed				
Salt	0.5	0.5	0.5	0.5
Minerals[1]	1	1	1	1
Sodium bicarbonate	1.5	1.5	1.5	1.5
Vitamin[2]	1	1	1	1
Bentonite	1	1	1	1
Chemical mixture (% of DM)				
Dry matter (% of as fed)	92.2	92	92.2	92
NEm (Mcal/kg)	2.20	2.21	2.20	2.21
NEg (Mcal/kg)	1.67	1.67	1.68	1.68
Crude protein	19.8	20	19.8	20
Ether extract	2.26	2.27	2.26	2.28
Neutral detergent fiber	11.2	11.5	11.2	11.5
Acid detergent fibre	6.31	6.33	6.32	6.34
Calcium	0.62	0.68	0.63	0.67
Phosphorus	0.50	0.55	0.51	0.54

WS=wheat straw, SB= sugarcane bagasse.
NEm = net energy for maintenance; NEg = net energy for growth.
[1]Mineral premix provided per kilogram of diet: Cu, 3300 mg/kg; Fe, 100 mg; Zn, 16 500 mg/kg; Mn, 9000 mg; I, 120 mg/kg; Co, 90 mg/kg; Se, 90 mg/kg.
[2]Vitamin premix provided per kilogram of diet: vitamin A, 200 000 IU; vitamin B, 300 000 IU; vitamin E, 10 000 IU; vitamin K, 2 mg; antioxidant 1000 mg/kg.

Growth performance: Throughout the experiment, the calves were weighed once every two weeks in the morning individually without prior deprivation of feed and water, and weight change was calculated by subtraction method. During the experiment, feed intake was measured daily by the difference between feed offered and feed refused.

Skeleton growth: To quantity skeletal growth, the parameters of the longitudinal line from the shoulder to rump as body length, the longitudinal line from the base of the rear feet to hook bones as the height of the withers, the longitudinal line from the base of the front legs to the withers for the height of the withers and the circumference of the chest as heart girth were measured at weaning time (56 days) and end of study (70 days) according to Nemati et al. (25).

Blood parameters: Blood samples were taken from the jugular vein, on days 30 and 65 of experiment 3 to 4 h after morning feeding, into two separate tubes (one with heparin and the other with no anticoagulant). Plasma and serum were collected by centrifuging the blood samples at 2000×g for 15 min at 4°C. The samples were kept at −80°C until analysis. The obtained plasma samples were analysed for glucose, triglyceride, urea, and beta-hydroxybutyric acid (BHBA) colorimetrically using commercial kits (imported by Pars Azmoon Co, Tehran, Iran from Hitachi 917, Modular P, Tokyo, Japan, and Randox, Antrim, UK).

No severe disease incidence occurred during the experiment. No mortality was observed among the experimental groups.

Ruminal fermentation: Rumen fluid sampling was performed on day 35 and at the end of the study period (70 days), at 3 hours after feeding in the morning by stomach tube technique. Rumen pH was measured immediately using a hand-held pH meter (HI 8314 membrane pH meter, Hanna Instruments, Villaf+ranca, Italy). For acidification of the rumen fluid, an aliquot (4 mL) was used with 1 mL of 25% meta-phosphoric acid and kept (−20 °C) until analysis for volatile fatty acids (VFA) by gas chromatography (0.25 × 0.32, 0.3 mm i.d. fused silica capillary, model no. CP- 9002 Vulcanusweg 259 a.m., Chrompack, Delft, the Netherlands) (18).

Statistical analysis: Statistical analyses were conducted using PROC MIXED (34) with the individual calf as the experimental. Given that growth performance was over time as repeated data was analyzed by relationship:

$$Y_{ij} = \mu + A_i + B_j + (A \times B)_{ij} + \beta(X_i - \bar{X}) + \varepsilon_{ij}$$

Where Y_{ij} is the dependent variable; μ is the overall mean, A_i is the effect of corn physical form (mashed vs. flacked), B_j is the effect of forage (hay vs. sugarcane bagasse), $(A\times B)_{ij}$ is the interaction between corn physical form and forage, $\beta(X_i-\bar{X})$ is the covariate variable (used only for BW with initial BW as a covariate) and εijk is the overall error term.

Results

Results related to the effects of corn grain processing with different fiber sources on the growth performance of Holstein calves are shown in Table 2. The source and type of forage (F) affected the growth performance of the calves (P<0.05). Whereas no effect from the C effect and an interaction effect between F and C groups were observed. Calves consuming the MCSB diet had a higher final body weight than those consuming FCWS and FCSB (P<0.05). The highest feed intake (the second months and the total period of the experimental) compared with other groups belonged to calves fed MCSB diet (P<0.05). Calves consuming the MCSB diet had a higher average daily gain during the first months and total period than those consuming FCWS and FCSB (P<0.05). So, this difference might be the result of the forage type whereas no effect from C factor was observed. An interaction was observed between the physical form of corn and the forage source for FCR during the second month (P<0.05). FCR was numerically improved for calves FCSB-fed diets than that other group in the second month, but this effect was not significant (P>0.05).

Results related to the effects of corn grain processing with different fiber sources on the performance skeleton of Holstein calves are shown in Table 3. The parameters of body length, hip and withers height, and heart circumference were no differences between treatments at weaning (d 56) or the final trial (d 65).

Results related to the effects of corn grain processing with different fiber sources on blood parameters of Holstein calves are shown in Table 4. Trial factors did not affect the concentration of triglyceride, urea, and beta-hydroxybutyric acid (BHBA). But the concentration of glucose was affected by F factors for 30 days. So, Calves fed on FCWS had the highest glucose, and calves fed on MCSB had the minimum value.

The results of volatile fatty acids (acetate, propionate, butyrate, and valerate) are presented in Table 5. Acetic acid and butyric acid were affected significantly by C and F treatment (P<0.05). Furthermore, there was an important effect (P<0.05) of C×F interaction on acetate of concentration at one and second months (P<0.05). But the concentration of butyrate was not affected by the C×F interaction effect. During the first month, propionic acid was affected by C, F, and C×F interaction effect (P<0.05). While, in the second month, the C factor and C×F interaction did not affect the concentration of propionate. At 30 days, the concentration of valeric acid was affected by C and F effect. But, no differences were observed in valeric acid among at d 65 of the study.

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Table 2. Effects of physical forms of corn (mashed and flaked) and forage source (sugarcane bagasse and wheat straw) on growth performance of dairy calves (*n* = 12 calves per treatment).

	Mashed corn		Flacked corn			P-value		
	WS	**SB**	**WS**	**SB**	**SEM**	**C**	**F**	**C×F**
Bodyweight (kg)								
Birth	38.18	38.06	38.22	38.19	0.69	0.90	0.90	0.94
Final	83.16[ab]	87.47[a]	80.29[b]	81.68[b]	1.63	0.15	0.005	0.55
Feed intake (g/d)								
1-30 day	262	284	236	223	23.06	0.85	0.06	0.45
31-60 day	1304[b]	1533[a]	1243[b]	1190[b]	57.36	0.13	0.001	0.01
1-65 day	769[b]	870[a]	717[b]	713[b]	23.64	0.06	0.001	0.03
Daily weight gain (g/d)								
1-30 day	307.74[ab]	359.21[a]	281.25[b]	303.30[ab]	20.74	0.08	0.05	0.47
31-60 day	759.63	845.78	738.21	761.23	36.44	0.32	0.06	0.70
1-65 day	656.5[ab]	705.25[a]	601.41[b]	621.45[b]	21.33	0.11	0.002	0.50
Feed conversion ratio								
1-30 day	0.89	0.80	0.88	0.75	0.082	0.19	0.72	0.81
31-60 day	1.65	1.84	1.73	1.56	0.084	0.90	0.25	0.03
1-65 day	1.17	1.24	1.22	1.14	0.049	0.91	0.68	0.15

[abc]Means within a row with different superscripts differ significantly, P<0.05.
WS=wheat straw, SB= sugarcane bagasse, C= physical forms of corn, F= forage source, C×F= the interactions between physical forms of corn and forage source.

Table 3. Effects of physical forms of corn (mashed and flaked) and forage source (sugarcane bagasse and wheat straw) on body measurements of suckling calves (*n* = 12 calves per treatment).

	Mashed corn		Flacked corn			P-value		
	WS	**SB**	**WS**	**SB**	**SEM**	**C**	**F**	**C×F**
Body length (cm)								
Birth (1 d)	45.08	46.00	45.75	47.00	1.25	0.87	0.15	0.69
At weaning (56 d)	54.25	55.66	57.08	56.33	3.55	0.06	0.60	0.17
Final (65 d)	60.08	59.66	61.41	60.36	3.47	0.30	0.43	0.73
Withers height (cm)								
Birth (1 d)	80.00	80.91	80.58	79.33	6.50	0.89	0.92	0.78
At weaning (56 d)	88.16	89.17	90.29	88.84	1.48	0.54	0.73	0. 07
Final (65 d)	91.16	92.58	93.58	92.50	1.85	0.09	0.76	0.06
Heart girth (cm)								
Birth (1 d)	79.41	80.66	80.50	80.33	1.47	0.47	0.81	0.12
At weaning (56 d)	95.26	96.83	97.13	96.58	4.43	0.33	0.99	0.30
Final (65 d)	100.50	101.04	102.32	101.33	7.22	0.17	0.60	0.26
Hip height (cm)								
Birth (1 d)	81.00	82.41	80.25	80.91	1.88	0.13	0.05	0.76
At weaning (56 d)	91.19	91.25	93.16	91.16	1.94	0.15	0.61	0.10
Final (65 d)	94.40	94.91	96.24	94.44	1.98	0.14	0.33	0.06

[abc]Means within a row with different superscripts differ significantly, P<0.05.
WS=wheat straw, SB= sugarcane bagasse. C= physical forms of corn, F= forage source, C×F= the interactions between physical forms of corn and forage source.

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Table 4. Effects of physical forms of corn (mashed and flaked) and forage source (sugarcane bagasse and wheat straw) on blood parameters of dairy calves (*n* = 12 calves per treatment).

	Mashed corn		Flacked corn			P-value		
	WS	SB	WS	SB	SEM	C	F	C×F
Glucose (µg/dL)								
30 day	97.50[b]	107.24[ab]	113.25[a]	106.25[ab]	5.80	0.11	0.02	0.54
65 day	73.25	70.25	80.75	76.25	3.50	0.009	0.57	0.07
Triglyceride (µg/dL)								
30 day	19.50	18.25	19.17	18.89	2.51	0.76	0.95	0.87
65 day	26.50	29.05	26.00	28.50	2.38	0.74	0.13	0.98
Urea (g/dL)								
30 day	22.14	21.57	20.00	23.82	1.70	0.004	0.002	0.18
65 day	25.00	26.23	27.37	28.25	1.65	0.38	0.001	0.69
BHBA (µmol/L)								
30 day	0.127	0.132	0.125	0.123	0.03	0.45	0.73	0.53
65 day	0.202	0.212	0.197	0.202	0.01	0.59	0.59	0.85

[abc]Means within a row with different superscripts differ significantly, P<0.05.
WS=wheat straw, SB= sugarcane bagasse, C= physical forms of corn, F= forage source, C×F= the interactions between physical forms of corn and forage source.

Table 5. Effects of physical forms of corn (mashed and flaked) and forage source (sugarcane bagasse and wheat straw) on the individual volatile fatty acids of the rumen fluid of dairy calves (*n* = 12 calves per treatment).

	Mashed corn		Flacked corn			P-value		
	WS	SB	WS	SB	SEM	C	F	C×F
Acetic acid								
30 day	62.32[a]	50.26[b]	50.16[b]	49.10[b]	0.82	0.001	0.001	0.001
60 day	75.12[a]	60.97[b]	59.42[b]	58.20[b]	1.11	0.001	0.001	0.004
Propionic acid								
30 day	22.75[c]	36.63[b]	35.30[b]	41.54[a]	1.29	0.001	0.001	0.018
60 day	23.21[b]	34.19[ab]	27.62[ab]	38.75[a]	3.27	0.290	0.009	0.986
Butyric acid								
30 day	10.88[b]	13.52[ab]	13.09[ab]	14.64[a]	0.76	0.059	0.024	0.491
60 day	8.12[c]	12.49[b]	15.20[a]	16.22[a]	0.81	0.054	0.095	0.258
Valeric acid								
30 day	1.59[b]	1.81[a]	1.37[c]	1.86[a]	0.35	0.008	0.015	0.740
60 day	1.21[b]	0.81[c]	1.50[a]	1.01[b]	0.21	0.291	0.073	0.823
pH								
30 day	5.4	5.3	5.2	5.2	0.6	0.54	0.88	0.89
60 day	5.5	5.3	5.3	5.2	0.5	0.55	0.65	0.82

[abc]Means within a row with different superscripts differ significantly, P<0.05.
WS=wheat straw, SB= sugarcane bagasse, C= physical forms of corn, F= forage source, C×F= the interactions between physical forms of corn and forage source.

Discussion and Conclusion

In the present study, the relatively low consumption of starter-containing flacked form corn can be related to the texture and physicality of the feed and the low digestibility of feed, reducing the rate of feed passage and increasing the mean retention time (MRT) of feed in the rumen. Rumen volume is one of the factors limiting the voluntary consumption of dry matter. In the ruminal wall, there are sensitive receptors that are stimulated against the stretching and expansion of the ruminoreticulum wall. In this way, they reduce the fermentation and digestion of feed in the rumen, which will eventually lead to a reduction in feed intake (22). In the current study, the forage factor affected body weight and daily weight gain of suckling calves. So, Calves fed the MCSB diet had better growth performance. Thus, the C effect was not significant. The inclusion of MCSB in the diet compared to other nutritional groups caused an increase in feed intake, as measured in the present study, and this issue in the studies of Bach et al. (3) and Porter et al. (33) approved. Imani et al. (16) Stated that adding forage increases feed intake, but this increase depends on the type of forage, the amount of forage, and the feeding method. So, the use of sugarcane bagasse compared to straw increased feed consumption (Table 2). It has been reported that the use of wheat straw increases the shelf life of feed in the rumen and spends more time on digestion and absorption. In contrast, the rate of ruminal emptying reduced due to the reduction of passage rate and feed consumption decreases (24). According to Khan et al. (21), the physical shape of the starting feed and the type of processing can make changes in the consumption of calf feed. Azimzade et al. (2) reported that the average body weight of calves fed cracked corn and steam-flaked corn was significantly higher than those fed whole corn and ground corn treatments at weaning and days 84. Franklin et al. (10) stated calves that consume pellet starter feed intake are higher compared with the ground starter. The researchers observed a decrease in feed intake in calves receiving flacked from corn and an increase in feed intake in calves receiving mashed versus textured (23, 27). However, Pazoki et al. (29) reported no differences in feed intake of suckling calves when comparing a ground starter feed with a textured starter feed. According to reports, the processing of grain and ingredients of starter feed can alter the rumen fermentation pattern and the nutrients digestibility (15, 28), thereby affecting starter intake and growth performance in dairy calves (29, 30). Regarding the effects of forage on the performance of claves, Imani et al. (16) stated that the consumption of starter feed intake in the ground or pelleted starter-fed calves is improved by supplementation with forage. Also, Mirzaei et al. (23) have observed increased ADG in calves provided with forage, either during the pre-weaning stage. But, these researchers did not observe any interactions between the physical forms of starter and forage provision on feed intake of calves during the pre-weaning periods. Castells et al. (7) described that the including of wheat straw in the diet of calves improved daily weight gain compared with alfalfa. In our study, the increased daily weight gains and feed intake of calves observed with the inclusion of SB in CM compared with WS supplementation were likely due to the sufficient supply of effective fibers to stimulate chewing activity and salivation, resulting in more rumen environment stability.

In the present work, experimental treatments did not affect the skeletal growth (length, hip and withers height, and heart circumference) of suckling calves. Terre et al. (36) reported that structural body measures (hip height, hearth circumference, and body size) were unaffected by texturized starter feed with or without straw, a pelleted starter feed plus straw offered to calves. Ghassemi-Nejad et al. (11) reported that length of body, withers and hip height, and heart girth of calves fed textured starter was not significant effect compared with those fed mashed. Nilieh et al. (26) showed that heart girth, body length, and hip height were not affected by the physical form of the starter diet or its interaction with alfalfa hay. However, Omidi-Mirzaei et al. (27) reported that body length, height and width hip, and heart circumference were greater for calves texturized offered feed starter feed than those fed coarsely mashed starter diets. Beiranvand et al. (6) described that body length, hip height, or hip-width of calves were not different by fed 10% hay. In the study of Mirzaei et al. (23), the body size of calves fed corn silage was higher than that of calves fed non-forage fiber. According to them, filling the gut can also be a confounding factor in determining the effects of forage on the body size measurement of dairy calves. Also, Kazemi-Bonchenari et al. (19) indicated body size of calves is not affected when diets contained no forage.

In the present study, the effects of corn grain processing with different fiber sources on triglyceride, urea, and BHBA content were not significant. But calves receiving FCWS diet had the highest and the MCWS diet had the lowest glucose at 30 days. Azimzadeh et al. (2) investigated the effect of corn processing (cracked corn and steam-flaked corn) on the blood of Holstein calves and reported that glucose, triglyceride, and beta-hydroxybutyric acid (BHBA) concentration were not affected by the experimental treatment. The physical form of the starter diet, forage inclusion, or their interaction according to the research of Nilieh et al. (26) could not change the levels of blood parameters such as glucose, beta-hydroxybutyric acid (BHBA), albumin, and total protein. However, in the present study, blood urea levels increased with the forage factor. This is our finding of blood urea levels according to a study by Phuong et al. (32) found that by including alfalfa in the diet of weaned calves, who observed an increase in blood urea, which was associated with low nitrogen efficiency with increased dietary fiber content.

In the present study, calves receiving MCWS diet had higher acetic acid concentrations compared to other treatments (Table 5). At 60 days, propionic acid and Butyrate acid concentrations were highest in FCSB treatment and lowest in MCWS treatment. The valeric acid concentration was affected by the forage factor. Thus, MCSB treatment had the lowest value compared to other treatments at 60 days. Research by Mirzaei et al. (23) has shown that the total amount of VFA rumen does not accurately indicate the amount of fermentation because their clearance rate is higher than their presence, but the ratio between individual VFA is probably an indicator of the type and process of fermentation. Beharka et al. (5) reported that calves fed with ground starter had no significant effect on the ratio of acetate to propionate compared to starter unground. Castells et al. (7) stated the highest total rumen VFA values in calves fed pelleted starter feed over the total trial period. Although the molar proportion of propionate was higher for pelleted starter feed but was no difference between treatments in the molar proportion of acetate, butyrate, and the acetate to propionate ratio. Nilieh et al. (26) stated that the higher SCFA value in the ruminal fluid of pelleted starter fed compared with coarsely mashed starter fed calves, as well as lesser ruminal pH in these animals, representing that pelleted starter form, has perhaps faster break down compared to the coarsely mashed starter. According to Castells et al. (7), acetate levels in the ruminal fluid of calves consuming forage supplements (alfalfa hay or oat hay) were higher than those of calves supplemented with non-forage fiber. Mash form of the starter as well as the wheat straw positively influenced acetate concentration in the ruminal fluid. Mirzaei et al. (23) found that mashed starter feed produced more acetate in comparison with the texturized starter in dairy calves. Results reported herein for ruminal acetate proportions are by Terré et al. (36) who reported higher acetate pro-portions on forage inclusion (alfalfa hay or chopped oat hay) in the diet. Our results showed that feeding the coarsely mashed starter with wheat straw increased the molar proportion of acetate and decreased the molar proportion of butyrate in the ruminal fluid before. Forage may displace concentrate intake and shift rumen fermentation in favor of acetate rather than butyrate production and, thus, delay rumen papillary development (38).

In conclusion, mashed corn feed compared with flacked corn was able to increase feed intake and daily weight gain, and final body weight, especially with the type of forage from the sugarcane bagasse. Therefore, providing sugarcane bagasse into mashed corn feed affects the calf's performance. Whereas, providing sugarcane bagasse with flacked corn improved the concentration of propionate and butyrate in the ruminal fluid. Based on the results, feeding corn grain in mash form with sugarcane bagasse resulted in better growth performance and it could be suggested for suckling calves compared to flacked corn and wheat straw.

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Conflict of interest

The authors declare that they have no competing interests.

Author Contributions

SJ, JS and GRG conceived and planned the experiments. SJ and JS carried out the experiments. HA and RS planned and carried out the simulations. SJ, JS and GRG contributed to sample preparation. HA, RS and JS contributed to the interpretation of the results. SJ and SS took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript.

Data Availability Statement

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Ethical Statement

This study does not present any ethical concerns.

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