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Final Technical Report

Replacement of dry ground corn for rehydrated corn or high moisture corn with high vitreousness for lactating dairy cows

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SUMÁRIO

INTRODUCTION

Corn grain plays a crucial role as a primary energy source in the diets of confined dairy cows. It is encapsulated by pericarp, primarily composed of hemicellulose, cellulose, lignin, and proteins (Santiago-Ramos et al., 2018). In its whole form, corn grain exhibits significant resistance to bacterial and enzymatic degradation (Kang et al., 2021). Immediately beneath the pericarp is a thin layer known as the aleurone, serving the function of mineral and enzyme storage (Holmes et al., 2019). The majority of the grain consists of the endosperm, constituting approximately 83%, which can be either vitreous (hard) or floury (soft) endosperm, with the proportion varying based on hybrid genetics (Singh et al., 2014). Finally, the germ section contains the embryo, characterized by high fat and protein content (Holmes et al., 2019). In the context of dairy cows, the primary component of the corn grain is the endosperm, rich in starch. The digestion of starch provides glucose precursors crucial for lactose synthesis in the mammary gland, facilitating milk production (Allen and Piantoni, 2014).

The mechanical processing methods for corn grain can be categorized into thermal and non-thermal techniques, both aimed at breaking up the pericarp and enhancing digestibility (Kang et al., 2021). Processes such as grinding, crimping, and ensiling of the grain play a pivotal role in influencing the speed and site of nutrient digestion, thereby inducing changes in the efficiency of the energy derived from starch (Nunes et al., 2020).

In certain agricultural regions, particularly in specific tropical areas, the window for harvesting of high moisture grain is narrow and often coincides with period on intense rainfall (Ferraretto et al., 2018). In such cases, the utilization of rehydrated corn grain (**RCG**) presents itself as an intriguing alternative (Castro et al., 2019). However, it is important to note that RCG silage may exhibit lower ruminal and total-tract starch digestibility compared to naturally high moisture corn grain (**HMC**) silage. This is

attributed to the greater prolamin content in rehydrated silage (Ferraretto et al., 2013). The ensilage of natural moisture corn grain involves harvesting the grain at an earlier stage, when it is younger and possesses lower prolamin content. These practices effectively balance low costs with high nutritional quality throughout the storage process (Weiss, 2019). In both cases, the fermentation process during silage production breaks down the prolamins in the grain, complemented by a positive response in milk production from the animals (Arcari et al., 2016).

The combined utilizations of corn grain processing techniques, such as harvesting young grains and crimping, is not extensively documented in the literature. While studies have highlighted their positive effects on grain digestibility, ruminal fermentation, and fiber digestion (Ferraretto et al., 2018), there is a noticeable gap in research focusing on the combined impact of these processing methods on the productive performance of dairy cows. Notably, there is a scarcity of literature evaluating all three forms of corn: dry ground, rehydrated, and high moisture crimped, utilizing the same vitreous corn hybrid. We hypothesize that HMC would exhibit greater digestibility compared to dry ground corn (**DGC**), and RGC, leading to enhanced productive performance in dairy cows. The objective of this study was to assess the effects of replacement of DGC with either for RGC or HMC silage on nutrient intake and digestibility, milk yield and composition, microbial synthesis, ruminal fermentation profile, and blood parameters of lactating dairy cows.

MATERIALS AND METHODS

Animals, Diets, and Experimental Design

The study was approved by the Ethics Committee of animal use, Brazil (Protocol 60/2020) and was conducted at the Teaching and Research and Extension Dairy Farm of the Department of Animal Science, Universidade Federal de Viçosa (UFV), Brazil.

Nine Holstein dairy cows, comprising six cannulated and three non-cannulated individuals, with an initial average BW of 639.1 ± 15.07 kg, milk production of 30.4. ± 1.58, parity of 2.0 ± 0.50, and days in milk of 99.7 ± 10.70 were blocked based on milk yield and days in milk. They were then randomly assigned to a treatment sequence in a replicated 3×3 Latin square design. The cows were housed in individual free stalls with 12.7 m² per cow, had free access to water, and were fed experimental TMR three times a day at 0700, 1500, and 2100 h to 110% of the actual feed intake of the previous day. Daily records of the weight of feed offered and refused were maintained for all cows. Milking occurred three times a day at 0630, 1430, and 2030 h, with the cows brought to the sprinkler room 30 min before milking for the cooling process.

Three treatments were evaluated in the study: 1) control diet with concentrate based on DGC; 2) replacement of DGC for RGC silage, and 3) replacement of DGC for HMC silage. The remaining components of the diet were corn silage, Tifton hay, soybean meal, whole cottonseed, limestone, sodium bicarbonate, magnesium oxide, salt, mycotoxin adsorbent, and mineral premix (Table 1). Diets were formulated to meet the specifications of 17.5% CP, 22% starch, and 4.6% ether extract. Additionally, the diets were designed to achieve a MY of 30 kg/d of MY following the guidelines of

NASEM (2021). Each experimental period spanned 28 d, with the initial 14 d dedicated to cow adaptation and the subsequent 14 d allocated for data and sample collection.

Corn Grain Processing

The study was carried out using the same corn hybrid for all treatments (LG 76799 hybrid; Limagrain, Goiás, Brazil), which presented an average vitreousness of 88% (Dombrink-Kurtzman and Bietz, 1993). The grains were processed using a 350 S2 roller mill (Murska®, Ylivieska, Finland) powered by a tractor and subsequently ensiled in 500 L capacity polyethylene tanks, capable of storing of approximately 500 kg of RGC or HMC. The roller mill, equipped with a 15 kW electric motor, had a capacity of 5 t/h for wet grains, requiring 30-40 HP of energy. To prevent the development of bacteria and fungi, an inoculant composed of propionic acid (90.5%; Lupro-Grain®, BASF S.A., São Paulo, Brazil), was utilized at a dose of 5 L/ton. The average density of the silos was 1100 kg/m³.

Dry grains of the same hybrid (LG 36799) were utilized for both RGC and DGC treatments, with the detailed in Table 2. The grains were ground with a Wiley mill (3-mm screen) with a moisture of 12%. For the RGC treatment, water was added to achieve a moisture level of 40%. An inoculant composed of propionic acid (90.5%; Lupro-Grain®, BASF S.A., São Paulo, Brazil) was employed to prevent de development of bacteria and fungi, applied at a dose of 5 L/ton. The silos for RGC had a density of 1100 kg/m³. Both HMC and RGC were stored for 258 d after the initial opening.

Sampling

On days 15 and 17 of each experimental period, milk samples were collected from each cow (350 mL) during each milking session using a mechanical milking electronic flow meter (GEA Westfalia Surge of Brazil, GEA Farm Technologies of Brazil, Indústria e Comércio de Equipamentos Agrícolas e Pecuários Ltda, Jaguariuna, São Paulo, Brazil). This process was conducted for three consecutive days, and the samples were then analyzed for fat, protein, and lactose content using an ultrasonic milk analyzer Lactoscan S LP (Milkotronic LTD, Nova Zagora, Bulgaria). Each milking time was analyzed separately for all parameters and then were averaged.

Samples of forages, concentrate ingredients, RGC, HMC, and TMR were collected from d18 to d21 of each experimental period and stored at -20°C until analysis. Throughout the experiment, three batches of concentrate mixes were prepared for each treatment, and individual concentrate ingredients were collected each time. Concentrate samples were obtained at the feed mill and stored at -20°C until analysis. All feed samples were dried at 55°C in a forced-air oven for 72 h and subsequently ground through a 1- and 2-mm screen using a Wiley mill (model 3; Arthur H. Thomas Co., Philadelphia, PA).

Fecal samples were collected for four consecutive days, from d18 to d20 of each period, directly from the animal's rectum. Subsequently, after the samples were placed in an aluminum tray, dried in a forced ventilation oven (55°C for 72 h) and processed in a knife mill at 1- and 2-mm screen using a Wiley mill (model 3; Arthur H. Thomas Co., Philadelphia, PA). Composite samples were created in proportion to the total dry weight of each collection day.

Ruminal digesta flow was determined by sampling omasal digesta, where five days before the actual sampling, 6.0 g/d of Co-EDTA was introduced into the rumen through the ruminal cannula every 4 h for 5 d, starting 3 d before the sampling. Six collections

of omasal digesta were performed at 9-h intervals utilizing the adapted technique developed by Huhtanen et al. (1997), resulting in three collection days per experimental period. The flow of omasal digesta was estimated using the digestion technique developed by Faichney (1975) with a double-marker system, this system involved the use of cobalt as the liquid phase marker and indigestible NDF (**NDFi**) as the particle phase marker, with measured at different stages of digestion. Sampling packaging and composite sampling for each animal followed the methodology described by Rotta et al. (2014).

To analyze ruminal fermentation, rumen content samples were collected at d21 of each experimental period, through the rumen cannula. The pH was measured using a pHmeter (Tecnal Tec-3MP, Piracicaba, São Paulo, Brazil), and a rumen sample was stored at -20°C for subsequent analysis of VFA.

Blood samples were collected from all cows at d25 through tail vessels approximately 4 h after feeding on the last day of each experimental period. Coagulation activator tubes with serum separating gel (BD Vacutainer®, Becton, Dickinson and Company, Franklin Lakes, NJ) were used. Tubes with clot activator and sodium fluoride (BD Vacutainer® Fluorinated/EDTA, São Paulo, Brazil) were employed to quantify plasma glucose concentration. Body condition score evaluation at d25 utilized the method described by Ferguson et al. (1994), with an average of three trained evaluators obtained on the same day as cows were weighed with a tape (Enevoldsen and Kristensen, 1997).

The total rumen evacuation procedure was conducted at d26 and d28 to estimate rates of passage and digestion (Allen and Linton, 2007). On d26, 4 h after feeding and on d28, immediately after delivering feed to the cows to represent maximum and minimum ruminal content, all rumen contents were removed and filtered through a

double layer of cheesecloth for separation into solid and liquid fractions. These fractions were collected in 60 L plastic barrels for each, weighed, and samples (approximately 2.0-3.0 kg). The samples were then placed in a 55°C forced air oven for 72 h, weighed, and ground to 1 mm for further analysis. Afterward, the remaining content was immediately remixed and replaced in the rumen. The reconstitution of the complete diet was calculated by proportioning particle and liquid components of the ruminal content in DM basis through the sampled content. The average DM content for particle over the two days of collection was determined, and the same /procedure was followed for the liquid content. The averages of these contents were then added to obtain the reconstituted DM content.

Laboratory Analysis

Samples of feed, ruminal digesta, omasal digesta, and feces underwent analysis for DM **(**method G-001/2 and method G-003/1), ash (method M-001/2), CP (method N-001/2, N × 6.25, Kjeldahl method), NDF (method F-002/2), and ether extract (**EE**; method G-005/2) following the procedures outlined by Detmann et al. (2021). Starch analysis was conducted using the acetate buffer method as described in Hall (2009).

VFA and ammonia analyses were performed using HPLC chromatography (Shimadzu LC-20AT, Kyoto, Japan) following the techniques outlined by Sigfried et al. (1984) for VFA and Chaney and Marbach (1962) for ammonia. For urea, cholesterol, and glucose analyses, the equipment BS-380 Mindray (Shenzhen, Guandong, China) was utilized, while NEFA analysis employed the equipment AU680 – Beckman Coulter (Brea, California, US). IGF-1 analysis was conducted using the Immulite equipment (Siemens, Erlangen, Germany) was used.

Samples of ensiled corns from HMC and RGC were analyzed for the mycotoxins incidence according to the Enzyme Linked Immuno Sorbent Assay (ELISA).

Statistical Analysis

Data was submitted to analysis of variance using the function lmer of lme4 package of R (R Core Team, 2023), according to the followed model:

$$Y_{ijklm} = \mu + T_i + LS_j + (T \times LS)_{ij} + A_{(j)k} + P_{(j)l} + \varepsilon_{ijklm}$$

where: Y_{ijklm} = dependent variable; μ = overall mean; T_i = fixed effect of treatment; LS_j = random effect of Latin square; $T \times LS_{ij}$ = random effect of interaction between treatment and Latin square (this effect was not significant for all variables and was removed from the model); $A_{(j)k}$ = random effect of animal within Latin square; $P_{(j)l}$ = random effect of period within Latin square and ε_{ijklm} = random error.

Variables measured over time were incorporated as repeated measures in the model, and the most appropriate covariance matrix was selected based on the lowest Akaike Information Criterion with a Correction. Tukey's test was employed to separate means when necessary, with differences considered significant at $P < 0.05$ and tendencies noted when $0.05 \leq P < 0.10$.

RESULTS AND DISCUSSION

Intake, Milk Production and Composition

The DMI significantly differed among treatments, with HMC exhibiting greater intake compared to DGC ($P = 0.03$) (Table 3). Additionally, CP intake was notably higher for both HMC and RGC compared to DGC ($P < 0.001$). Notably, NDF intake was also significantly higher for HMC in comparison to the other treatments ($P = 0.04$).

Typically, finely ground corn and high-moisture corn are known to enhance starch availability while potentially reducing DMI (Ferraretto et al., 2013). Research on finishing dairy bulls fed barley employing various conservation techniques demonstrated higher DMI and CP intakes among bulls consuming crimped barley compared to those fed dry barley grain (Huuskonen et al., 2020). These findings align with the results of our study, suggesting a positive influence of the crimping method on intake. Huhtanen (1984a) noted that high-moisture ensiled barley exhibited greater palatability compared to dry barley grain, resulting in higher DMI (kg/kg $BW^{0.75}$). This observation aligns with the DMI pattern observed in our study.

Milk yield showed a tendency to be greater (P = 0.09) for HMC in relation to DGC (Table 4), possibly due to greater DMI of this treatment. Milk fat content was greater for RGC and HMC (P = 0.04) when compared to DGC, the findings contrast with those of numerous other studies, with total solids displaying a tendency to increase. Related to milk protein and lactose contents no difference or tendency (P > 0.10) were observed. Observing studies which reported corn processed forms like steam flaked, ensiled high moisture corn, and rehydrated corn, it is usually observed maintenance in milk production and decrease in DMI, improving feed efficiency (Ferraretto et al., 2013; Martins et al., 2019). The observed trend in milk yield suggests a potential for increasing milk production in systems utilizing HMC. Specifically, HMC showed an increase of 8.4% compared to the DGC treatment and 5.8% compared to the RGC treatment.

Rumen pH, VFA, and Digestibility

The ruminal pH (Fig 1) was not different among treatments and has an interaction between treatment and time ($P < 0.001$). The values were not critical in a general way, the pattern of rumen pH along the time was as expected, showing minor values around 4 hours after feeding time, at time 0, 12 and 18. Only once for DGC and RGC the ruminal values reached value under 5.8 of pH, and twice for HMC this value was reached, indicating that cows were not in subclinical acidosis, which can be enhanced by the fat content of the milk. The daily averages of pH were greater to 6.0 for all treatments, and coherent when compared to other studies with similar processing types and starch levels that showed values greater than 6 of pH (Oba and Allen, 2003; Castro et al., 2019).

The percentage values of VFA were similar between treatments (Table 5), but these values are greater for acetate, around 60% of VFAs in literature and approximately 66% in this study, and smaller for propionate that reach values close to 25% in other studies and 20% in this study (Castro et al. 2019; Ahmadi et al. 2020). The butyric values were close to obtained in Castro et al. (2019). These differences can be attributed to diets used. Iin this study, NDF was included in smaller quantity, but the digestibility was smaller. Additionally, the starch content in this study was lower compared to the reported studies.

Digestibility of DM did not differ among treatments (Table 6), as well as NDF and starch, despite the long storage time of 258 d for RGC and HMC. However, CP digestibility was greater ($P = 0.02$) for HMC when compared to DGC, probably due to this type of processing corn promoting proteolytic enzymatic degradation of CP (Bach et al., 2005).

The flow of DM was greater ($P = 0.04$) for ensiled processed corns, following the tendency of greater DMI for these treatments, which may have led to this result. Ruminal

degradability was equal for DM, starch, and NDF among treatments, as well as reported by other studies (Joy et al., 1997; Ferraretto et al., 2013).

Urea excretion, microbial protein, and microbial efficiency

The RGC and HMC showed greater values of urea excretion (Table 7) that can explained due to greater DMI of these treatments (Savari et al., 2018). Microbial protein production and microbial efficiency tended to be greater in RGC and HMC (Table 7). This like due to these processing form improve the availability of starch for microbials, and the RGC tended to favor greater intestinal availability of starch (Moharrery et al., 2014).

Blood Metabolites

The greater value for NEFA (P = 0.03; Table 8) of HMC indicates that treatment trigger greater reserves mobilization compared to fine ground corn, in this treatment insulin peak is achieve faster and levels decrease faster, making it possible the return of increase levels of NEFA (Allen, 2023).

Mycotoxins detection

In both the HMC and RGC treatments (as detailed in Table 9), the incidence of mycotoxins was remarkably low. Only one sample from RCG and another from HMC exhibited the presence of Toxin-T2. It's noteworthy that the European Union has set a limit of 500 ppb for Toxin-T2 in cereals. Moreover, a solitary sample from HMC contained 34.9 ppb of Zearalenone, still well below the 500 ppb limit for this mycotoxin. Additionally, three samples from HMC revealed the presence of Ochratoxin A, with an average of 4.2 ppb, below the 250 ppb limit established for this toxin. It's worth

mentioning that when consumed alone in naturally occurring doses, Ochratoxin A doesn't pose significant toxicity to cattle, and its carry-over into milk is minimal.

In summary, both HMC and RGC treatments appear safe for dairy cattle feeding, given the minimal presence of mycotoxins.

General responses and perspectives

The conducted research has confirmed the usability and applicability of the tested technology for processing high-moisture corn grains in Brazilian agriculture. Therefore, this technology has potential to be incorporate as a new method for processing corn in dairy farms.

The impact of the results obtained in this study could be profoundly significant from a farmer's perspective. For instance, considering a farm with 50 lactating cows, an average milk yield of 28.6 L/cow/day, and a milk price of 2.30 R$/L, the observed increase in milk yield of 8.4% when comparing HMC with DGC would translate to a boost in income of 100,840 R$/year, by the increase in milk yield from 28.6 to 31 L/cow/day.

Another way to gauge the positive impact of this increase in milk yield is by utilizing the technical index of Income over Feed Costs (IOFC). This index, based on the gross margin concept, evaluates the daily output (milk) of a lactating cow and subtracts the highest variable cost, which is the feed expense. The resulting figure represents gross income, which can then be allocated towards covering expenses such as dry cow and heifer feed, dairy directs, overheads, owner withdrawals, and loan payments.

Considering the daily feed intake of DGC and HMC obtained in this study, the feed cost for a cow producing 28.6 L/day will be around 35.5 R$/day, while for cow producing 31 L/day will be around 38.8 R$/day. Considering the previously mentioned milk price (2.30 R$/L), for a cow producing 28.6 L/day, the IOFC would be 30.3 R$/day. However,

for a cow with an average yield of 32.5 L/day, the IOFC would increase to 32.4 R$/day. This represents a notable 7% increase in the daily gross income per cow, illustrating a remarkable perspective for dairy farmers.

Another advantageous perspective for the use of HMC silages is the possibility of vacating the area earlier. This would enable farmers to utilize the land for other crops, such as a second corn planting, beans, or to sow temperate forages like oat. In the present study, the harvest for HMC silage occurred 28 days earlier than for the other treatments, resulting in approximately 21% less land utilization for the same crop. While it is beyond the scope of this study to evaluate the impact of this earlier harvest on the production system, as we did not assess the implementation of a second crop in this area, it is evident that the early harvest will benefit the production system. This is because the planting of a second crop could occur earlier in the season, potentially coinciding with more precipitation, which could positively impact its growth. While it is not quantifying, the earlier harvest could be viewed as a strategy to reduce the likelihood of losses due to bird attacks on the corn plants, which is a common issue in many regions of Brazil, as well as potential pest attacks.

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TABLES AND FIGURES

Table 1. Ingredient and nutrient composition of diets with different corn processing methods

	DGC[1]	RGC[2]	HMC[3]
Ingredients (%, DM basis)			
Corn silage	51.2	51.2	51.2
DGC	16.0	0.0	0.0
RGC	0.0	16.0	0.0
HMC	0.0	0.0	16.0
Soybean meal	14.0	14.0	14.0
Whole cottonseeds	8.2	8.2	8.2
Tifton Hay	5.7	5.7	5.7
Minerals and vitamins premix[4]	1.85	1.85	1.85
Sodium bicarbonate	0.90	0.90	0.90
Bicalcium fosfate	0.53	0.53	0.53
Magnesium oxide	0.45	0.45	0.45
Limestone	0.45	0.45	0.45
Urea	0.43	0.43	0.43
MilkSacc+	0.13	0.13	0.13
Flowers of sulphur	0.09	0.09	0.09
V-Max 2[5]	0.04	0.04	0.04
Mycosorb A	0.04	0.04	0.04
Diet Composition (% DM)			
DM, as fed	45.0	45.0	45.0
CP	17.5	17.8	17.7
RDP	11.2	11.4	11.4
RUP	6.3	6.4	6.3
Starch	22.2	22.2	21.7
NDF	32.5	31.8	31.5
NDF_{forage}	25.5	25.5	25.5
Ether extract	4.3	4.6	4.4

[1]DGC= dry ground corn; [2]RGC=rehydrated ground corn; [3]HMC= high moisture corn, [4]calcium: 180 (g/kg);

phosphorus: 40 (g/kg), magnesium: 25 (g/kg); sodium: 75 (g/kg); sulfur: 20 (g/kg); copper: 594 (mg/kg); zinc: 3.000 (mg/kg); , manganese: 2.475 (mg/kg); selenium: 16.5 (mg/kg); cobalt: 45 (mg/kg); iodine: 34.10 (mg/kg); Vitamin A: 300.000 (UI); Vitamin D3: 90.000 (UI); Vitamin E: 1.440 (mg/kg); Proviox: 360 (mg/kg); Biotin: 50 (mg/kg); Monensin: 600 (mg/kg). [5] Virginamycin 2%.

Table 2. Nutrient composition of corn treatments used in the experiment.

Items, % DM basis	DGC[1]	RGC[2]	HMC[3]
Dry matter	89.0	58.4	49.5
Organic matter	98.1	98.7	99.0
Crude protein	8.42	9.20	8.61
Starch	70.5	70.6	68.9
Neutral detergent fiber	8.32	6.81	6.66
Ether extract	3.13	4.96	3.48

[1]DGC= dry ground corn, RGC=Rehydrated ground corn, [3]HMC=high moisture corn

Table 3. Dry matter (kg/d) and nutrient intake (kg/d in DM basis) in dairy cows fed with different corn processing methods.

Items (kg/d)	DGC[1]	RGC[2]	HMC[3]	SEM	*P*-value
Dry matter	19.1[b]	19.8[ab]	21.1[a]	1.43	0.03
Organic matter	17.3[b]	17.8[ab]	18.9[a]	1.29	0.04
Crude protein	3.34[b]	3.52[ab]	3.73[a]	0.229	< 0.01
Neutral detergent fiber	6.21[b]	6.30[b]	6.65[a]	0.482	0.04
Ether extract	0.82[b]	0.91[a]	0.93[a]	0.074	0.04
Starch	4.24[b]	4.40[ab]	4.57[a]	0.26	< 0.01

[1]DGC= dry ground corn, [2]RGC=Rehydrated ground corn, [3]HMC=high moisture corn

Table 4. Milk yield and milk composition in cows fed with different corn processing methods.

Items	DGC[1]	RGC[2]	HMC[3]	SEM	*P*-value
Yield, kg/d					
Milk	28.6^{B}	29.3^{AB}	31.0^{A}	2.84	0.09
ECM	26.5^{B}	27.9^{AB}	29.6^{A}	2.37	0.05
Fat	1.03^{b}	1.12^{ab}	1.19^{a}	0.723	0.03
Protein	0.88	0.90	0.95	0.727	0.14
Lactose	1.32	1.35	1.43	1.081	0.13
Total solids	3.23^{b}	3.37^{ab}	3.57^{a}	0.273	0.04
Milk composition, %					
Fat	3.59^{b}	3.81^{a}	3.86^{a}	0.232	0.04
Protein	3.06	3.08	3.07	0.044	0.75
Lactose	4.60	4.59	4.61	0.065	0.87
Total solids	11.7^{B}	12.2^{AB}	12.3^{A}	0.28	0.08
Feed efficiency, kg/kg	1.50	1.48	1.47	0.068	0.60
BW, kg	650	655	662	16.3	
BCS	3.23	3.23	3.28	0.109	

[1]DGC= dry ground corn; [2]RGC= rehydrated ground corn; [3]HMC= high moisture corn

[ab]Means in a row with differing superscripts differ at P≤0.05 by the Tukey's test

[AB] Means in a row with differing superscripts representing statistical tendency at P>0.05<0.10 by the Tukey's test

Table 5. Ruminal ammonia and VFA concentration in ruminal samples of dairy cows fed different corn processing methods.

Item	DGC[1]	RGC[2]	HMC[3]	SEM	*P*-value
Ammonia, mg/L	75.9^{B}	88.5^{A}	88.4^{A}	6.33	0.09
Acetic, %	66.9	66.5	66.1	1.22	0.61
Propionic, %	20.8	21.1	20.7	0.74	0.74
Butyric, %	8.51	9.40	9.55	0.73	0.22
Isobutyric, %	1.85	1.36	0.25	1.254	0.15
Valerate, %	0.87	0.96	0.83	0.135	0.61
Isovalerate, %	2.02^{B}	2.41^{AB}	2.61^{A}	0.306	0.07
Acetic/propionic, %	3.25	3.17	3.22	0.163	0.72

[1]DGC= dry ground corn; [2]RGC= rehydrated ground corn; [3]HMC= high moisture corn

[ab]Means in a row with differing superscripts differ at P≤0.05 by the Tukey's test

[AB] Means in a row with differing superscripts representing statistical tendency at P>0.05<0.10 by the Tukey's test

Table 6. Total tract apparent digestibility, ruminal flow, and ruminal digestibility in dairy cows fed different corn processing methods.

	DGC[1]	RGC[2]	HMC[3]	SEM	*P*-value
Total tract apparent digestibility (%)					
Dry matter	59.3	58.1	59.1	1.63	0.48
Crude protein	68.1[b]	71.7[a]	73.1[a]	1.90	<0.01
Neutral detergent fiber	48.8	49.2	49.5	0.98	0.87
Starch	97.3	97.6	97.7	0.57	0.73
Ruminal flow (kg/d)					
Dry matter	8.81[b]	10.07[ab]	10.6[a]	0.6590	0.04
Neutral detergent fiber	4.49	4.72	5.03	0.4860	0.45
Starch	0.96	1.13	1.22	0.0998	0.13
Rumen digestibility (% of total)					
Dry matter	53.4	51.0	48.6	3.72	0.21
Neutral detergent fiber	48.5	48.4	48.6	2.30	0.18
Starch	81.1	77.9	78.5	2.32	0.35

[1]DGC= dry ground corn; [2]RGC= rehydrated ground corn; [3]HMC= high moisture corn

Table 7. Urea excretion, microbial protein, microbial efficiency of dairy cows fed different corn processing methods.

Item	DGC[1]	RGC[2]	HMC[3]	SEM	P-value
Urea excretion, g/kg of OM	158[b]	220[a]	223[a]	8.06	<0.001
Microbial protein, g/day	2929[B]	3362[B]	3295[AB]	228	0.070
Microbial efficiency, g/day	287[B]	325[A]	297[AB]	17.6	0.053

[1]DGC= dry ground corn; [2]RGC= rehydrated ground corn; [3]HMC= High moisture corn

[ab]Means in a row with differing superscripts differ at P≤0.05 by the Tukey's test

[AB] Means in a row with differing superscripts representing statistical tendency at P>0.05<0.10 by the Tukey's test

Table 8. Blood metabolites of dairy cows fed with different corn processing.

Item	DGC[1]	RGC[2]	WCC[3]	SEM	P-value
Cholesterol, mg/dL	154	178	169	17	0.275
Urea, mg/dL	36.4	41.1	39.6	2.58	0.434
IGF-1, ng/mL	128	130	135	26.0	0.867
NEFA, mmol/L	0.0700[b]	0.0878[ab]	0.1056[a]	0.0102	0.030
Glucose, mg/dL	53.9	53.0	55.3	1.6	0.298

[1]DGC= dry ground corn; [2]RGC= rehydrated ground corn; [3]WCC= wet crimped corn
[ab]Means in a row with differing superscripts differ at P≤0.05 by the Tukey's test
[AB] Means in a row with differing superscripts representing statistical tendency at P>0.05<0.10 by the Tukey's test

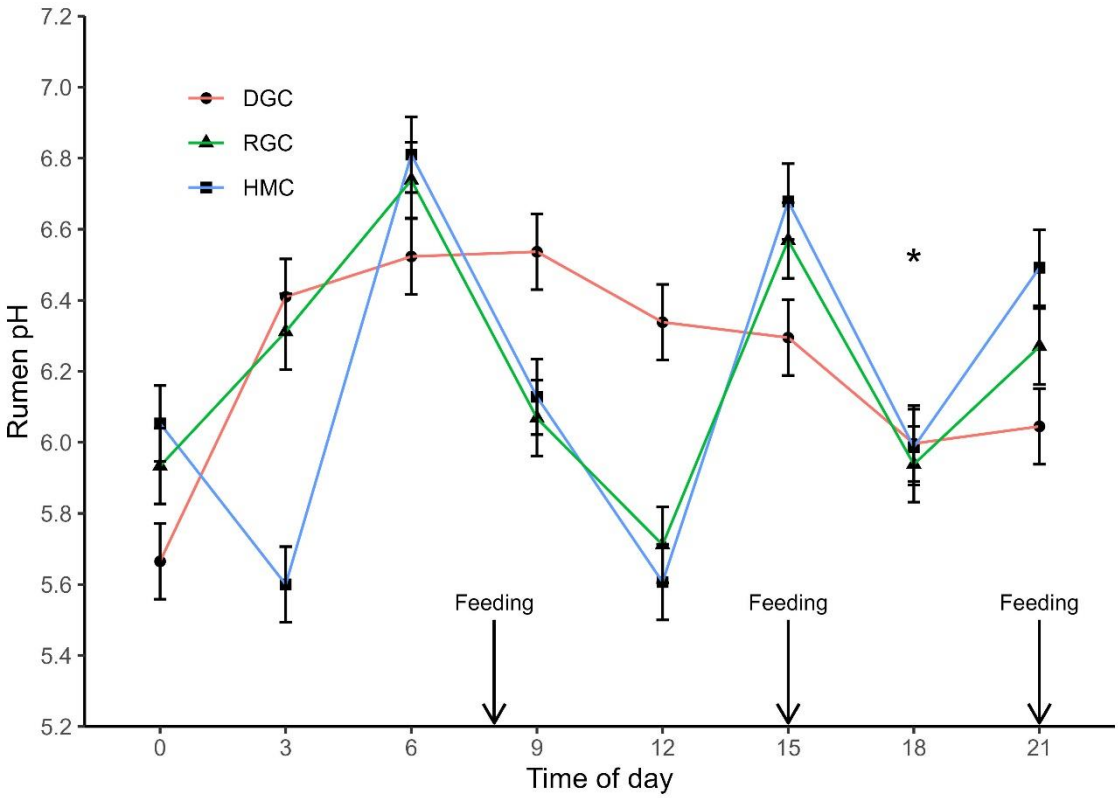
Table 9 – Incidence of mycotoxins according to the different corn processing methods.

Item (ppb)	Sample					
	1	2	3	4	5	6
High moisture corn grain						
Aflatoxin	ND	ND	ND	ND	ND	ND
Deoxynivalenol	ND	ND	ND	ND	ND	ND
Fumonisins	ND	ND	ND	ND	ND	ND
Ochratoxin A	3.5	ND	6.1	ND	ND	3.2
Toxin-T2	23.8	ND	ND	ND	ND	ND
Zearalenone	ND	34.9	ND	ND	ND	ND
Rehydrated corn grain						
Aflatoxin	ND	ND	ND	ND	ND	ND
Deoxynivalenol	ND	ND	ND	ND	ND	ND
Fumonisins	ND	ND	ND	ND	ND	ND
Ochratoxin A	ND	ND	ND	ND	ND	ND
Toxin-T2	ND	ND	ND	ND	29.1	ND
Zearalenone	ND	ND	ND	ND	ND	ND

ND = not detected.

Figures

Figure 1. Ruminal pH along the time of day among treatments with the three-feeding delivery time. * Time that no differences were observed among treatments.



Martins, Fig 1.