The effect of dry corn gluten feed on chewing activities and rumen parameters in lactating dairy cows

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ABSTRACT

The objectives of this research were to evaluate the effects of increasing levels of dry corn gluten feed (DCGF) on dry matter intake (DMI), chewing activity, and rumen fermentation when used to replace a portion of corn silage in diets for lactating Holstein cows. Eight lactating Holstein primiparous cows averaging 98±20 d in milk and weighing 515±20 kg were randomly assigned in a 4x4 Latin square design with 4 week periods. Dietary treatments were 1) a control diets (C) of 50% forage (corn silage and wheat straw, 35%, 15% DM basis, respectively), 2) a low DCGF diet (L-DCGF) in which 10% of the same corn silage was replaced by DCGF, 3) a medium DCGF diet (M-DCGF) in which 18% of the same corn silage was replaced by DCGF, and 4) a high DCGF diet (H-DCGF) in which 25% of the same corn silage was replaced by DCGF.

The proportion of particles retained on the 19.0 mm screen and physical effectiveness factor of the H-DCGF was lower (P<0.05) than in the other groups. Increasing the level of DCGF did not change DMI. Cows fed the C diet spent significantly more time ruminating and chewing per day compared with the M-DCGF and H-DCGF diets (483.88, 435.63, 431.25 min/d, P<0.05; and 818.38, 753.00, 745.75 min/d respectively, P<0.05). Cows fed the C diet had ruminal pH values higher than the cows fed the M-DCGF and H-DCGF diets (6.02, 5.95, and 5.91, P<0.05). The total volatile fatty acid and propionate levels of H-DCGF fed cows were higher than the control (P<0.05). The changes in acetate (A) and propionate (P) concentrations resulted in a decrease in A/P ratio, when corn silage was replaced by DCGF, which led to a reduction in the particle size of the diets (P<0.05). It was concluded that when ratio 18 and 25% DCGF were substituted for corn silage, ruminating time, chewing activities and ruminal pH are negatively affected. The optimum level for the addition of DCGF was found to be below 18% of the diet for a healthy rumen and a chewing behaviour in dairy cows.

Key Words: Dry corn gluten feed, Particle size, Rumen pH, Chewing activity.

RIASSUNTO

INTRODUZIONE DI GLUTINE DI MAIS DISIDRATATO NELLA RAZIONE ALIMENTARE: EFFETTI SULL’ATTIVITÀ Masticatoria E SULLA RUMINAZIONE IN VACCHE DA LATTE IN LATTAZIONE

L’obiettivo di questo lavoro è stato quello di valutare gli effetti di quantità crescenti di glutine di mais disidratato (DCGF) nella razione alimentare, in sostituzione parziale dell’insilato di mais, sulla sostanza
secca ingerita (DMI), sull’attività masticatoria e sulla fermentazione ruminale in vacche Holstein in lat- tazione. Otto bovine Holstein primpire di peso medio di 515±20 kg, in lattazione mediamente da 98±20 d, sono state distribuite a random secondo un disegno a Quadrato Latino 4x4 con periodi diquat- tro settimane. I trattamenti dietetici sono stati: 1) dieta di controllo (C) costituita per il 50% da forag- gio (insilato di mais e paglia di frumento, 35% e 15% della sostanza secca, rispettivamente), 2) dieta a bassa concentrazione di DCGF (L-DCGF) dove il 10% dell’insilato di mais è stato sostituito da DCGF, 3) dieta a media concentrazione di DCGF (M-DCGF) dove il 18% dell’insilato di mais è stato sostituito da DCGF, e 4) dieta ad alta concentrazione di DCFG (H-DCGF) dove il 25% dell’insilato di mais è stato sostituito da DCGF.

La percentuale di frazioni alimentari trattenute dalla setacciatura (19 mm) e il fattore di efficienza fisica della dieta H-DCGF sono risultati inferiori (P<0.05) rispetto agli altri gruppi. Incrementando la somministra- zione di DCGF non si sono verificati cambiamenti nell’assunzione di sostanza secca ingerita. Gli ani- mali alimentati con la dieta C hanno aumentato in misura significativa il tempo di ruminazione e l’atti- vità masticatoria rispetto agli animali alimentati con le diete M-DCGF e H-DCGF (483,88, 435,63, 431,25 min/d, P<0,05; e 818,38, 753,00, 745,75 min/d rispettivamente, P<0,05). Nelle vacche alimentate con la dieta C è stato registrato un pH ruminale più elevato rispetto a quello delle bovine alimentate con le diete M-DCGF e H-DCGF (6,02, 5,95, e 5,91, P<0,05). I livelli di acidi grassi volatili e dell’ac. propionico sono risultati più alti nel trattamento dietetico H-DCGF rispetto alla dieta di controllo (P<0,05). Alla ridu- zione di granulometria delle diete (P<0,05) provocata dalla parziale sostituzione dell’insilato di mais con DCGF ha fatto seguito la variazione delle concentrazioni di acido acetico e di acido propionico, con ridu- zione del rapporto A/P.

In conclusione la parziale sostituzione, 18% e 25%, di DCGF all’insilato di mais provoca effetti negativi sul tempo di ruminazione, sulla masticazione e sul pH ruminale. Il livello ottimale di somministrazione di DCGF atto a garantire la funzionalità ruminale e un adeguato comportamento di masticazione nelle bovi- ne da latte è risultato essere al di sotto del 18% della dieta.

Parole chiave: Glutine di mais disidratato, Granulometria, pH ruminale, Masticazione.

Introduction

A co-product of wet milling of corn, corn gluten feed is primarily a mixture of corn bran and fermented corn extractives (steep liquor). The bran is then mixed with steep liquor and sold as wet corn gluten feed (WCGF) or with water removed, as dry corn gluten feed (DCGF). Both the dry and wet forms of corn gluten feed have their advantages and require special attention when receiving and storing it. WCGF has distinct storage requirements but can be handled in a variety of ways. WCGF should be placed in a sealed structure to reduce spoilage. When stored in an open pile for a few days in warm weather, mould growth develops and a rapid spoilage occurs. Texture of the wet product restricts flow and makes handling difficult, thus offering a cost benefit to producers near a wet milling plant. However, DCGF is available as flakes or pellets. Also DCGF is easier to store and handle, and feed is more available to a greater number of dairy producers than WCGF. DCGF is often flash dried to about 90% dry mat- ter (DM). Although DCGF contains 40 to 45% neutral detergent fibre (NDF), it only contains 3% lignin and is a source of highly digestible fibre. When incorporating nonforage sources of fibre, such as DCGF, into rations for ruminants, one should take into account the effective NDF content, and the interactions between forage and nonforage fibra for ruminal digestion (Allen and Grant, 2000).

There has not been satisfying research data in terms of using DCGF as nonforage source in dairy cow diets. Firkins et al. (1991) suggested that the combination of 20% DCGF and 1% sodium bicarbonate was an effective replacement for NDF from corn silage. Replacing a portion of alfalfa hay, corn silage, and corn grain with WCGF increased dry matter intake (DMI), and production efficiency (VanBaale et al., 2001).
Nonforage sources of fibre do not stimulate rumination activity as effectively as dietary forage because of their small particle size (Mertens, 1997). Therefore, it is important to consider the effective NDF content of these fibre sources. Yet, there is no absolute maximal, or optimal amount of fibrous (DCGF) co-product feed that can safely replace dietary forage for a complete lactation. Also, present data in the literature is unfortunately inadequate to infer an upper limit for DCGF as nonforage fibre source in the diet of dairy cows.

The objectives of this research were to evaluate the effects of increasing levels of DCGF on DMI, chewing activity, and rumen fermentation when used to replace a portion of corn silage in lactating Holstein cows.

Material and methods

Forages and dry corn gluten feed
Corn silage was obtained from Uludag University (Turkey), Faculty of Veterinary Medicine farm. Whole plant corn (hybrid C955, Monsanto Company, St. Louis, MO, USA) was harvested at about 26.5% DM using a self-propelled forage harvester (without kernel processing unit; Tosun Tarim, Izmir, Turkey). The chopped forage was placed in a horizontal silo (300 ton capacity), covered with nylon plastic, and ensiled for approximately 3 months. Wheat straw was chopped using a miller rotary hay mill (Model No: S8002, Tosun Tarim) equipped with a 5-cm screen. The DCGF was delivered from Cargill (Bursa, Turkey) and same DCGF used to throughout the experimental period.

Cows and diets
Eight lactating Holstein primiparous cows averaging 98±20 kg in milk and weighing 515±20 kg were randomly assigned in a 4x4 Latin square design with 4 week periods. Each period was 30 d; the last 10 d were used for sample and data collection. One of the two cows in each group was cannulated ruminally with soft plastic cannulas of 10 cm internal diameter (Ankom, pliable rumen cannula # 29, 4 inches, NY, USA). Cows were housed and fed individually in a tie stall and stanchion barn and had free-choice access to water. Fibre sources compared were corn silage and DCGF. All DCGF used in this experiment was received from the same source found to have consistent composition. The DCGF contained 24.7% crude protein (CP), 42.7% NDF, 13.0% acid detergent fibre (ADF) and 2.4% lignin on DM basis.

Dietary treatments were 1) a control diets (C) of 50% forage (corn silage and wheat straw, 35%, 15% DM basis, respectively), 2) a low DCGF diet (L-DCGF) in which 10% of the same corn silage was replaced by DCGF, 3) a medium DCGF diet (M-DCGF) in which 18% of the same corn silage was replaced by DCGF, and 4) a high DCGF diet (H-DCGF) in which 25% of the same corn silage was replaced by DCGF. Corn grain was also added to the diets with DCGF in order to make the diets isocaloric and isonitrogenic. In addition, soybean meal and extruded soybean seed amounts were reduced as the DCGF levels were raised in the diets. All diets were fed as total mixed rations (TMR) and were formulated to meet or exceed the requirements of a 515 kg cow producing 25 kg milk/d containing 3.4% milk fat, 3.0% true protein, and 4.8% lactose, according to NRC (2001). TMR were mixed once daily and fed for ad libitum intake twice daily at 0900 and 1800 h. The amount of feed offered was adjusted daily to obtain approximately 10% orts. Body weight (BW) was measured for two consecutive days immediately before morning feeding and the weights were averaged.

Sample collection and analysis
Feed offered and orts were measured and recorded daily during the last 10 d of the period to calculate feed intake. The TMR were collected once weekly for particle distribution analysis and DM determination. The samples were dried in 55°C oven for 48 h, and then ground through a 1-mm diameter screen for
analysis of NDF, ADF, starch, ether extract, ash and CP. Analytical DM content of the samples was determined by drying at 105°C for 12 h (AOAC, 1990). The ash was determined by combustion at 550°C for 6 h. The NDF, ADF and lignin contents were determined using the methods described by Van Soest et al. (1991) with amylase (Sigma no. A3306; Sigma Chemical Co., St. Louis, MO, USA), and sodium sulfite used in the NDF procedure. Starch was determined using a colorimetric assay including a refined corn starch sample as described by Bal et al. (2000), and CP was determined by the Kjeldahl method (AOAC, 1990). Weekly DM and NDF analyses were performed on TMR samples, which were dried in a forced-air oven at 55°C for 48 h.

**Chewing activities**

Eating and ruminating behaviours were monitored visually for a 24-h period in eight cows. Eating and ruminating activities were noted every 5 min, and each activity was assumed to persist for the entire 5-min interval. To estimate the time spent eating per kilogram of DMI, the actual intake for that day was used. A period of rumination was defined as at least 5 min of rumination occurring after at least 5 min without ruminating activity. When estimating the number of rumination periods per kilogram of DMI, or time spent ruminating per kilogram of NDF intake, the average daily intake measured in that period was used, because time spent ruminating was assumed to reflect the DMI of the previous days. Total time spent eating was calculated as the total time spent eating and ruminating.

**Particle size analysis**

The Penn State Particle Separator (PSPS) was used to measure particle size for TMR as described by Kononoff et al. (2003). Physically effective NDF (peNDF) is defined as that dietary fibre source which effectively stimulates rumination and salivation. The peNDF was estimated by multiplying the concentration of NDF in the diet by the amount of DM retained on the 1.18 mm sieves (Mertens, 1997). Subsequent to sieving, material was removed from each sieve and dried in a forced air oven at 55°C to determine the amount of DM retained on each sieve. Percent of DM retained on each sieve were calculated as outlined by the ASAE-S424 (2001).

**Ruminal pH and fermentation**

Ruminal contents were sampled from canulated cows in one-hour intervals throughout 24-h periods on d 19 and 20. Approximately 0.5 L of ruminal contents was obtained from the anterior dorsal, anterior ventral, medial ventral, posterior dorsal, and posterior ventral locations within the rumen, and composited for one cow. Each sample was strained immediately through four layers of cheesecloth. Rumen pH was determined immediately with a portable electronic pH meter from each sample collected (Inolab pH, serial no: 00200018, pH-Electrode SenTix 41, D-82362, Weihen, Germany). Samples of the 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, and 24 h collection were divided into sub-samples for the determination of volatile fatty acid (VFA) and NH₃-N. The samples for VFA were acidified with 2 ml of 25% metaphosphoric acid, and centrifuged at 5000 rpm for 10 min. Supernatant was frozen (-20°C) for subsequent analyses. Rumen NH₃-N was determined by the hypochlorite phenol procedure (Beecher and Whitten, 1978). The VFAs were determined by using a gas chromatograph (Hewlett Packard Agilent Technologies 6890N Network GC System, Serial CN10447002, Beijing, China). A column (6x2mm ID glass) was packed with 10% SP-1200/1% H₃PO₄ 80/100 Chromosorb WAW (Supelco, Bellefonte, PA, USA). The carrier gas (N₂) flow was 30 ml/min, inlet temperature was 175°C, column temperature was 110°C, and detector temperature was 170°C. Detection was by flame ionisation.
Statistical analyses

Data were analysed as a replicated 4x4 Latin square design with model effects for square, cow within square, period, treatment, and square x treatment using the general linear models of SPSS (version 10.0, SPSS Inc, Chicago, USA). If treatment effects were significant, means were compared using Least Squares Differences (Snedecor and Codran, 1989). Unless otherwise stated, significance was declared at P<0.05.

Results and discussion

Ration composition and particle size

Dietary formulation and nutrient analysis are shown in Table 1. All of the diets had different DM amounts, due to the usage of corn silage and DCGF in varying percentages in the diets. The starch and NFC amounts of the rations with DCGF were higher, since they had higher corn grain content than the control diet. However, NDF levels decreased parallel to the increasing DCGF levels in the rations. This is related to the lower NDF content of DCGF compared to corn silage (42.70 versus 56.43%).

Table 2 provides the particle distributions and peNDF of the TMR. The particle size of the diets reflected their DCGF in the diets. The proportion of particles retained on the 19.0 mm screen and physical effectiveness factor (pef) of the H-DCGF was lower (P<0.05) than in the other groups. Numbers of the particle sizes larger than 19 mm gradually decreased as the DCGF ratio increased in the diets. Parallelly, the ratio of the particles smaller than 1.18 mm increased. The peNDF contents of the diets were 31.01, 29.51, 27.12 and 25.69% of DM, for C, L-DCGF, M-DCGF and H-DCGF diets, respectively (P<0.05).

Feed intake

The DMI, NDF intake (NDFI) and BW are shown in Table 2. Increasing the level of DCGF did not change DMI or intake as a percentage of body weight. However, NDFI and NDFI as a percentage of body weight between C and M-DCGF diets, and also between C and H-DCGF diets differed significantly (P<0.05). This can be due to insignificant variations between the groups from the aspect of DMI, and the gradual decrease in the NDF content of the diet by the inclusion of DCGF. Van Baale et al. (2001) concluded that when WCGF is substituted for both a portion of the forage and corn in the diet, dairy cows will have increased DMI. In contrast, Droppo et al. (1985) also replaced a portion of the grain and soybean meal with WCGF and reported decreased DMI. Although not significant, this study suggests a similar DMI when DCGF was added to the diet. Cows fed the diets containing DCGF had smaller intake of peNDF than did cows fed the control diet, because particle size of the diet and the estimated pef for C were higher than those of DCGF diet. In proportion of peNDF in the diets varied from 25.69 to 31.01% of DM within the minimum recommendation ranges. Mertens (1997) recommended that 19.7% peNDF was required to maintain a milk fat percentage of 3.4% for Holstein cows, and 22.3% peNDF was needed to maintain an average ruminal pH of 6.0. However, it is apparent that peNDF did not influence feed intake despite different pef contents of the diets.

Chewing activity, ruminal pH, and VFA

The chewing activities are shown in Table 3. Cows fed the C diet spent significantly more time ruminating and chewing per day compared with the M-DCGF and H-DCGF diets. However, the eating times of the diets were found to be similar. By decreasing the dietary particle size with replacement of the corn silage, chewing activity was reduced for the DCGF diets. These results are similar to Allen and Grant (2000) who observed that chewing activity decreased 24.4% with the addition of WCGF diet fed to lactating dairy cows. Several researchers (Beauchemin and Yang, 2005; Beauchemin et al., 2003) observed a positive correlation between the ruminating time and the peNDF. In the present study, peNDF values
Table 1. Ingredients and chemical composition of the total mixed diets.

| Item                          | Control        | Dry Corn Gluten Feed |
|-------------------------------|----------------|----------------------|
|                               | 10%            | 18%                  | 25%                  |
| Ingredients (% Dry Matter):    |                |                      |                      |
| Corn silage                   | 35.00          | 25.00                | 17.00                | 10.00                |
| Wheat straw                   | 15.00          | 15.00                | 15.00                | 15.00                |
| Dry corn gluten feed          | -              | 10.00                | 18.00                | 25.00                |
| Corn grain ground             | 26.41          | 32.18                | 36.27                | 37.30                |
| Soybean meal 44% CP           | 14.17          | 12.51                | 10.22                | 8.19                 |
| Soybean seed extruded         | 7.39           | 3.28                 | 1.41                 | 2.41                 |
| Dicalcium phosphate           | 0.31           | 0.31                 | 0.32                 | 0.32                 |
| Calcium carbonate             | 1.36           | 1.36                 | 1.41                 | 1.41                 |
| Vitamin-mineral premix        | 0.05           | 0.05                 | 0.05                 | 0.05                 |
| Salt (NaCl)                   | 0.31           | 0.31                 | 0.32                 | 0.32                 |
| Chemical composition:         |                |                      |                      |
| Dry matter                    | %              | 49.90                | 56.85                | 64.02                | 70.40                |
| Crude protein % DM            | 14.59          | 14.14                | 14.24                | 14.25                |
| Ether extract                 | %              | 4.32                 | 3.60                 | 3.54                 | 3.54                 |
| Neutral detergent fibre %     | 36.86          | 36.10                | 34.46                | 33.71                |
| FNDF2                         | %              | 30.45                | 25.8                 | 21.6                 | 18.8                 |
| Acid detergent fibre %        | 22.95          | 21.16                | 19.51                | 17.75                |
| NFC1                          | %              | 35.9                 | 38.8                 | 40.6                 | 41.0                 |
| Starch                        | %              | 27.19                | 29.45                | 31.28                | 33.80                |
| Ash                           | %              | 7.46                 | 7.25                 | 7.42                 | 7.55                 |
| NE\textsuperscript{4} Mcal/kg of DM | 1.61 | 1.61                 | 1.63                 | 1.64                 |

\textsuperscript{1}Supplied per kilogram of premix (Kavimix VM, Kartal Kimya A.S., Gebze, Turkey): Vitamin A 12,000,000 U; Vitamin D3, 3,000,000 U; Vitamin E 30 g; Mn 50 g; Fe 50 g; Zn 50 g; Cu 10 g; I 0.8 g; Co 0.1 g; Se 0.15 g; Antioxidant 10 g.

\textsuperscript{2}FNDF: Percentage neutral detergent fibre from forage, calculated from ingredient analysis.

\textsuperscript{3}NFC: Nonfiber carbohydrate, %; calculated as: 100 - (NDF, % + CP, % + EE, % + ash, %).

\textsuperscript{4}NE\textsubscript{x}: Net energy lactation; Calculated from NRC (2001).

and the ruminating times of M- and H-DCGF diets were found to be lower than those of the control.

Dairy cows consuming large quantities of DM tended to ruminate more than 6 h daily, unless a digestive upset occurs (Beauchemin et al., 1994). This is equivalent to a minimum 16 min/kg of DM for 22 kg/d of DMI. In this study, the shortest rumination time was calculated as 24.9 min/kg of DM for cows fed the H-DCGF, with the lowest pNDF intake among the four diets studied. Furthermore, Sudweeks et al. (1981) proposed chewing corrected for DMI as a criterion for physical effectiveness of diets. They further proposed values equal or more than 30 min/kg of DMI as suitable for limiting the risk of
Table 2. Dietary particle size distribution, peNDF, NDFI and DMI values of total mixed diets (DM basis).

| % DM retained | Control | Dry Corn Gluten Feed |
|---------------|---------|----------------------|
|               | 10%     | 18%                  | 25% |
| >19.0 mm      | 6.70     | 4.90                 | 4.70 |
| 19.0 to 8.0 mm| 30.93    | 18.60                | 11.40 |
| 8.0 to 1.18 mm| 46.50    | 58.25                | 62.60 |
| <1.18 mm      | 15.93    | 18.25                | 21.23 |
| 1 peNDF % of DM| 0.84    | 0.82                  | 0.79 |
| 2 peNDF % of DM| 31.01   | 29.51                | 27.12 |
| 3 NDFI kg/d of DM| 6.58    | 6.31                | 5.84 |
| 4 NDFI % of body weight| 1.24     | 1.19                | 1.10 |
| 5 DMI kg/d    | 17.86    | 17.47                | 16.95 |
| 6 DMI % of body weight| 3.35    | 3.31                | 3.18 |
| Body weight, kg| 534.50    | 528.00       | 532.75 |

DM = Dry matter intake.
NDFI = NDF intake.
peNDF = Physical effectiveness factor.

SEM = Standard error mean.

\(^1\)Physical effectiveness factors (pef) were determined by the fraction retained on a 1.18 mm sieve using horizontal shaking with Penn State Particle Separator.
\(^2\)peNDF was determined after burning the samples according to the method of Mertens (1997).
\(^3\)NDFI = NDF intake.
\(^4\)DMI = Dry matter intake.
\(^5\)SEM = Standard error mean.

\(a-d\): Means in the same row with different superscript letters are significantly different \((P<0.05)\).

Disorders. In this study, cows chewed more than 30 min/kg of DM.

Effects of dietary treatments on ruminal pH, VFA and NH₃-N values are presented Table 4. Control diet-fed cows had the highest ruminal pH. Cows fed C diet had ruminal pH values higher than the cows fed M-DCGF and H-DCGF diets \((P<0.05)\). Besides, ruminal pH of the H-DCGF diet was lower than that of the L-DCGF diet \((P<0.05)\). This can be related to the chewing activity, which stimulates salivary secretion of bicarbonate and phosphate buffers, causing an increase in the ruminal pH. The decline observed in the ruminal pH by manipulating the DCGF and corn grain of diets was likely due to decreased rumination time. Lower ruminal pH was constant with less time spent chewing for diets containing 18%, and 25% DCGF, respectively. Furthermore, higher starch from corn grain and also the inclusion of NDF in decreasing amounts in DCGF diets were possibly an additional factor contributing to low ruminal pH.

DCGF and corn grain amount in the diet had a significant effect on ruminal pH and ruminal VFA content, molar proportion of acetate, propionate, butyrate, and acetate: propionate ratio in the present trial. The total VFA and propionate concentrations of H-DCGF diet fed cows were higher than C \((P<0.05)\). This can be related to the relatively high starch content of this diet. Diets that increase chewing time and saliva flow may lower the concentration of VFA because saliva flow has a dilution effect and increases the turnover rate of rumen liquid (Sudweeks, 1977). Krause and Combs (2003) reported that propionate concentration tended to increase when alfalfa silage...
**Table 3. Effects of dietary treatments on chewing behaviour.**

|                     | Control | Dry Corn | Gluten Feed | 1SEM |
|---------------------|---------|----------|-------------|------|
|                     |         | 10%      | 18%         | 25%  |
| **Eating**          |         |          |             |      |
| Min/d               | 334.5   | 326.4    | 317.4       | 314.5|
| Min/kg of DM        | 18.8    | 18.8     | 19.1        | 18.2 |
| Min/kg of NDF       | 51.1    | 52.1     | 55.4        | 54.1 |
| **Ruminating:**     |         |          |             |      |
| Min/d               | 483.9a  | 459.4ab  | 435.6b      | 431.3b|
| Min/kg of DM        | 27.0    | 26.5     | 26.2        | 25.0 |
| Min/kg of NDF       | 73.4    | 73.4     | 75.9        | 74.2 |
| **Total chewing:**  |         |          |             |      |
| Min/d               | 818.4a  | 785.8ab  | 753.0bc     | 745.8b|
| Min/kg of DM        | 45.9    | 45.3     | 45.2        | 43.2 |
| Min/kg of NDF       | 124.4   | 125.6    | 131.3       | 128.2|

1SEM = Standard error mean.

a-b: Means in the same row with different superscript letters are significantly different (P<0.05).

**Table 4. Effects of dietary treatments on ruminal pH, VFA and NH$_3$-N values.**

|                 | Control | Dry Corn | Gluten Feed | 1SEM |
|-----------------|---------|----------|-------------|------|
|                 |         | 10%      | 18%         | 25%  |
| pH              | 6.02a   | 5.99ab   | 5.95bc      | 5.91c|
| Total VFA       | 70.94a  | 72.48ab  | 74.34bc     | 77.51a|
| (mmol/L)        |         |          |             |      |
| VFA (Mol/100 mol): |       |          |             |      |
| Acetate (A)     | 63.38a  | 60.35a   | 59.50ab     | 59.27b|
| Propionate (P)  | 23.38a  | 25.52b   | 25.65ab     | 27.49a|
| Butyrate        | 9.58a   | 9.94ab   | 10.47a      | 9.83a |
| Isobutyrate     | 0.52b   | 0.58a    | 0.56a       | 0.50b |
| Isovalerate     | 1.41c   | 1.37c    | 1.48b       | 1.54a |
| n-Valerate      | 1.73c   | 2.24a    | 2.34a       | 1.37c |
| A/P             | 2.71a   | 2.36b    | 2.32b       | 2.16b |
| NH$_3$-N        | 12.57   | 13.29    | 12.29       | 13.24|
| (mg/dL)         |         |          |             |      |

1SEM = Standard error mean.
a-c: Means in the same row with different superscript letters are significantly different (P<0.05).
was partially replaced by corn silage, probably due to an increase in the amount of dietary starch. Another reason for this can be the reduced particle size in the DCGF diet. Krause et al. (2002) stated that the concentration of propionate increased when particle size was decreased. Acetate content was the highest in the C. This might be due to the higher the NDF content of C compared to other diets. AP ratio had decreased in parallel to the increase in the DCGF, and to the decrease in particle size of the diets. Ruminal NH₃-N concentration was similar in all of the diets.

Conclusions

Rumination time, chewing activities and ruminal pH were negatively affected when DCGF was substituted in 18 and 25% ratio for corn silage. The optimum level of DCGF inclusion for rumen health and chewing behaviour in dairy cows fed these diets was below 18% of the diet. However, one should keep in mind that the decrease in ruminal pH could be both related to increased DCGF and corn grain content in the diets.

DCGF is an excellent co-product feedstuff for dairy cattle when economics are favourable and limitations are taken into account. Further research is needed in this area to extend knowledge in forage replacement to DCGF in dairy cow rations.

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