Journal of Agricultural Science and Technology A 16 (2026) 36-43
doi: 10.17265/2161-6256/2026.01.005

# Performance of Dairy Cows Fed High Moisture Corn or Rehydrated Corn Grain Silages with the Addition of Sodium Benzoate

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**Abstract:** The objective of this study was to evaluate the effects of sodium benzoate inclusion in high moisture corn (HMC) and rehydrated corn grain (RCG) silages on silage fermentation profile, nutrient digestibility, feeding behavior, and performance of lactating Holstein cows. Silages were prepared in 200-L drums (n = 6 per treatment) and treatments were arranged in a 2 × 2 factorial design: grain source (HMC or RCG) and additive (without or with 0.2% sodium benzoate, fresh basis). Twenty-four Holstein cows were assigned to a replicated 4 × 4 Latin square design. Sodium benzoate reduced ($P < 0.01$) butyric acid, ethanol, and other fermentation end-products (Table 2), and tended to reduce soluble protein concentration. Total-tract starch digestibility increased ($P = 0.05$) with sodium benzoate inclusion (Table 4), resulting in increased milk yield (+0.8 kg/d; $P = 0.05$) (Table 5). Feeding behavior was altered, with greater chewing time and meal frequency (Table 6). No differences were observed between HMC and RCG regarding animal performance. Rehydrated corn grain silage was as effective as HMC as a starch source for dairy cows. Sodium benzoate improved fermentation quality and milk production without negatively affecting intake.

**Key words:** Chemical additive, fermentation profile, grain silage, milk production, starch digestibility.

## 1. Introduction

Ensiling corn grain is widely adopted in dairy production systems due to improvements in starch availability and total-tract digestibility. Fermentation promotes prolamin degradation, increasing starch accessibility [1, 2].

High moisture corn (HMC) and rehydrated corn grain (RCG) differ in harvest moisture and microbial epiphytic populations, which may influence fermentation dynamics [3]. Rehydrated corn grain may present lower natural LAB populations, potentially increasing undesirable microorganisms.

Sodium benzoate is an antifungal preservative that inhibits microbial growth via intracellular acidification [4]. However, its antimicrobial action could potentially interfere with proteolysis during ensiling, affecting starch digestibility.

Although additives improve aerobic stability [5-7], animal performance responses remain inconsistent. Therefore, this study hypothesized that:

1. HMC and RCG would present distinct fermentation patterns.
2. Sodium benzoate would modify fermentation and proteolysis.
3. These changes would influence milk production and feeding behavior.

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## 2. Material and Methods

### *2.1 Site, Ethical Approval, and General Conditions*

The trial was conducted at the University of São Paulo, in the experimental dairy free-stall facilities of the Luiz de Queiroz College of Agriculture (ESALQ/USP), Piracicaba, SP, Brazil. All procedures involving animals followed institutional guidelines and were approved by the Ethics Committee for Animal Use of the University of São Paulo (protocol 2018.5.1093.11.4).

### *2.2 Silage Preparation and Treatments*

2.2.1 Crop Management and Harvest

A single corn hybrid (30F53; Pioneer, Brazil) was sown in December 2017 in two adjacent field areas with a 3-week planting interval to allow harvest at different grain moisture contents on the same date.

High moisture corn (HMC) was harvested at physiological maturity (kernel black layer) with approximately 35% moisture. A second area was harvested at less than 20% moisture to obtain dry corn grain for rehydrated corn grain silage (RCG) preparation.

HMC grains were processed using a roller mill adjusted to crack kernels into 5–6 pieces. Dry grain was ground through a 5-mm screen and rehydrated to reach 33% moisture. Moisture content was determined after drying samples at 55 °C for 24 h to calculate water addition.

2.2.2 Experimental Treatments

Treatments were arranged in a 2 × 2 factorial design:

- Grain source: HMC or RCG
- Additive: without (CON) or with sodium benzoate (BEN)

Sodium benzoate was applied at 0.2% fresh matter (2 kg $t^{-1}$). For RCG, the additive was diluted in water during rehydration. For HMC, sodium benzoate was mixed for 20 min in a vertical mixer wagon. Control HMC received equivalent water addition, eliminating mixing bias. Silages were stored in 200-L plastic drums (24 drums per treatment), achieving an average density of 1,200 ± 50 kg as-fed. Silos were stored for 80 days before feeding.

### *2.3 Experimental Design and Animals*

The feeding trial was conducted as a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of treatments (grain source × additive). Each period lasted 21 days (15 days adaptation and 6 days sampling).

Twenty-four lactating Holstein cows (12 primiparous and 12 multiparous) were used. At trial initiation, cows averaged 30.3 ± 3.8 kg $d^{-1}$ milk yield, 601.6 ± 82.6 kg body weight, and 85 ± 28.7 days in milk. Four rumen-cannulated cows were used for ruminal measurements. Diets were offered twice daily allowing 5–10% refusals. Mineral and vitamin supplementation followed NRC [8]. Ingredients, nutrient composition and particle distribution of experimental diets are presented in Table 1.

### *2.4 Chemical Analyses*

Silage, total mixed ration (TMR), orts, and fecal samples were dried at 55 °C for 72 h and ground through a 1-mm screen. Dry matter, ether extract, and ash were determined according to AOAC [9]. Crude protein was analyzed using the Dumas combustion method [10]. Neutral detergent fiber (NDF) was analyzed according to Mertens [11] using heat-stable amylase and sodium sulfite. Starch concentration was determined according to Hall [12]. Indigestible NDF (iNDF) was determined after 288 h ruminal in situ incubation and used as an internal marker to estimate total-tract apparent digestibility [13]. Total-tract apparent digestibility was calculated as:

$$\text{Digestibility (\%)} = 100 - (\text{TMR iNDF} / \text{fecal iNDF}) \times (\text{fecal nutrient concentration} / \text{TMR nutrient concentration})$$

**Table 1 Ingredients and nutrients composition of the experimental diets with corn grain stored as high moisture corn silage (HMC) or reconstituted corn grain silage (RCG), without (CON) or with sodium benzoate (BEN) (mean ± SD; n = 6 cows/ treatment).**

| Item | HMC | | RCG | |
|---|---|---|---|---|
| | CON | BEN | CON | BEN |
| Ingredients, % of diet dry matter | | | | |
| Corn silage | 38.3 ± 0.80 | 38.3 ± 0.80 | 38.2 ± 0.80 | 38.2 ± 0.76 |
| Oat haylage | 10.6 ± 0.87 | 10.6 ± 0.87 | 10.6 ± 0.86 | 10.6 ± 0.87 |
| Corn grain source | 16.8 ± 0.14 | 16.9 ± 0.14 | 16.9 ± 0.15 | 16.9 ± 0.11 |
| Citrus pulp | 12.8 ± 0.08 | 12.8 ± 0.08 | 12.7 ± 0.11 | 12.8 ± 0.11 |
| Soybean meal | 16.1 ± 0.11 | 16.1 ± 0.11 | 16.1 ± 0.08 | 16.1 ± 0.11 |
| Rumen protected soybean meal | 2.8 ± 0.05 | 2.8 ± 0.05 | 2.8 ± 0.05 | 2.8 ± 0.05 |
| Mineral mix[1] | 2.5 ± 0.05 | 2.5 ± 0.05 | 2.5 ± 0.04 | 2.5 ± 0.04 |
| Nutrients, % of dry matter | | | | |
| Dry matter, % as fed | 48.5 ± 0.31 | 48.6 ± 0.31 | 48.6 ± 0.31 | 48.6 ± 0.34 |
| Crude Protein | 16.4 ± 0.19 | 16.3 ± 0.18 | 16.5 ± 0.17 | 16.5 ± 0.20 |
| Neutral detergent fiber | 37.4 ± 1.27 | 37.2 ± 1.27 | 37.2 ± 1.25 | 37.2 ± 1.25 |
| Ash | 7.72 ± 0.095 | 7.73 ± 0.092 | 7.71 ± 0.111 | 7.69 ± 0.110 |
| Ether extract | 3.16 ± 0.079 | 3.23 ± 0.049 | 3.12 ± 0.118 | 3.20 ± 0.064 |
| Starch | 27.1 ± 1.00 | 27.7 ± 0.85 | 27.3 ± 1.14 | 27.6 ± 0.78 |
| Non-fiber carbohydrates | 42.1 ± 0.18 | 42.1 ± 0.17 | 42.2 ± 0.18 | 42.1 ± 0.20 |
| Starch origin, % of total starch | | | | |
| Corn Silage | 50.8 ± 1.27 | 49.8 ± 1.91 | 50.4 ± 2.07 | 49.8 ± 1.89 |
| Grain silage | 44.4 ± 1.69 | 45.8 ± 2.07 | 45.0 ± 1.90 | 45.5 ± 2.07 |
| Penn State Separator sieves, % retained as-fed | | | | |
| 19 mm | 20.1 ± 6.6 | 22.8 ± 6.5 | 19.8 ± 5.4 | 20.7 ± 4.3 |
| 8 mm | 26.5 ± 1.2 | 24.9 ± 0.8 | 24.9 ± 1.0 | 25.1 ± 2.2 |
| 1.18 mm | 40.9 ± 4.1 | 41.1 ± 2.7 | 43.0 ± 2.1 | 41.1 ± 3.7 |
| Bottom pan | 12.5 ± 2.9 | 11.3 ± 3.5 | 12.3 ± 3.9 | 13.2 ± 2.9 |

[1] Mineral

### *2.5 Fermentation Profile and Aerobic Stability*

Silage extracts were prepared by homogenizing 25 g of silage with 225 g of distilled water. pH was measured immediately. Lactic acid was determined according to Pryce [14]. Volatile fatty acids, alcohols, and esters were analyzed using gas chromatography. Dry matter was corrected for volatile losses according to Weissbach [15]. For aerobic stability, 3 kg of silage per treatment were exposed to air at 25 °C for 10 days. Temperature was recorded every 30 min. Silage was considered unstable when temperature increased 2 °C above ambient temperature.

### *2.6 Intake, Milk Production, and Feeding Behavior*

Dry matter intake (DMI) was calculated as feed offered minus refusals. Milk yield was recorded daily. Milk samples were analyzed for fat, protein, lactose, and milk urea nitrogen using mid-infrared spectroscopy. Energy-corrected milk (ECM) was calculated according to Tyrrell and Reid [16]. Fat-corrected milk (3.5% FCM) was calculated according to NRC [8]. Feeding behavior was recorded at 10-min intervals over 24 h. Chewing time was calculated as eating plus ruminating time. Sorting behavior was evaluated according to Leonardi and Armentano [17].

### *2.7 Ruminal Fermentation and Nitrogen Metabolism*

Ruminal samples were collected every 3 h over 24 h from cannulated cows. Ammonia-N concentration was determined colorimetrically according to Chaney and Marbach [18]. Urinary creatinine was used to estimate urinary output [19], and allantoin concentration was determined according to Chen and Gomes [20].

*2.8 Statistical Analysis*

Data were analyzed using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC, USA). Silage data were analyzed using the model:

$$Y = \mu + \text{period} + \text{grain source} + \text{additive} + \text{interaction} + \text{error}$$

Performance data were analyzed using a replicated Latin square model with cow nested within the square. Repeated measures were used for ruminal data including hour and its interactions. Means were declared significant at $P \leq 0.05$ and trends at $0.05 < P \leq 0.10$

## 3. Results

*3.1 Chemical Composition and Fermentation Profile*

Dry matter corrected for volatile compounds averaged 68.1% and did not differ between treatments (Table 2). Grain source affected crude protein (CP), with RCG presenting greater CP concentration than HMC (P = 0.01). Soluble protein concentration differed between grain sources (P = 0.01) and tended to decrease with sodium benzoate inclusion (P = 0.08).

**Table 2 Composition and fermentation profile of high moisture corn silages (HMC) or reconstituted corn grain silages (RCG), without (CON) or with sodium benzoate (BEN).**

| Item | HMC | | RCG | | SEM | *P*-value[1] | | |
|---|---|---|---|---|---|---|---|---|
| | CON | BEN | CON | BEN | | G | A | A x G |
| Nutrient | | | | | | | | |
| Dmcorr, % as fed | 67.8 | 68.1 | 68.2 | 68.4 | 0.18 | 0.13 | 0.19 | 0.84 |
| Crude protein, % DM | 8.78 | 8.73 | 9.74 | 9.47 | 0.137 | <0.01 | 0.12 | 0.27 |
| Soluble CP, % of CP | 60.0 | 55.2 | 52.7 | 50.6 | 2.98 | 0.01 | 0.08 | 0.48 |
| Starch, % of DM | 71.4 | 73.2 | 71.4 | 74.1 | 1.72 | 0.79 | 0.15 | 0.77 |
| Neutral detergent fiber, % DM | 7.91 | 7.37 | 7.88 | 7.44 | 0.426 | 0.95 | 0.11 | 0.87 |
| WSC, % DM | 0.54 | 0.88 | 0.89 | 0.99 | 0.117 | 0.04 | 0.05 | 0.26 |
| Fermentation profile | | | | | | | | |
| pH | 4.25 | 4.30 | 4.24 | 4.27 | 0.019 | 0.14 | 0.01 | 0.27 |
| Lactic acid, % of DM | 1.24 | 1.16 | 1.34 | 1.16 | 0.067 | 0.47 | 0.08 | 0.47 |
| Acetic acid, % of DM | 0.18 | 0.15 | 0.23 | 0.18 | 0.018 | <0.01 | 0.01 | 0.39 |
| Ethanol, % of DM | 0.24 | 0.11 | 0.19 | 0.07 | 0.045 | 0.28 | 0.01 | 0.90 |
| 1,2-Propanediol, mg/kg of DM | 91.0 | 69.6 | 112.4 | 40.6 | 13.08 | 0.78 | <0.01 | 0.08 |
| 2,3-Butanediol, mg/kg of DM | 41.0 | 23.3 | 78.9 | 26.5 | 16.03 | 0.12 | 0.01 | 0.18 |
| Propionic acid, mg/kg of DM | 18.5 | 14.4 | 18.7 | 15.0 | 1.04 | 0.70 | <0.01 | 0.86 |
| Ethyl lactate, mg/kg of DM | 80.1 | 36.0 | 63.4 | 23.2 | 10.52 | 0.10 | <0.01 | 0.82 |
| Ethyl acetate, mg/kg of DM | 15.46 | 3.94 | 15.39 | 4.28 | 2.461 | 0.98 | 0.10 | 0.97 |
| Butyric acid, mg/kg of DM | 8.16 | 3.84 | 14.38 | 4.87 | 2.045 | 0.06 | <0.01 | 0.16 |
| Isobutyric acid, mg/kg of DM | 2.83 | 2.13 | 2.03 | 3.60 | 1.071 | 0.76 | 0.70 | 0.31 |
| 1-propanol, mg/kg of DM | 1.45 | 1.92 | 2.31 | 2.88 | 0.553 | 0.07 | 0.29 | 0.92 |
| Acetone, mg/kg of DM | 9.20 | 14.29 | 23.53 | 30.81 | 7.534 | <0.01 | 0.12 | 0.68 |
| Methanol, mg/kg of DM | 25.1 | 22.7 | 33.7 | 23.6 | 4.70 | 0.33 | 0.20 | 0.42 |
| Isopropyl Alcohol, mg/kg of DM | 0.93 | 0.63 | 0.67 | 0.64 | 0.212 | 0.54 | 0.41 | 0.50 |
| Propyl Acetate, mg/kg of DM | 0.69 | 0.51 | 0.66 | 0.65 | 0.209 | 0.79 | 0.64 | 0.68 |
| Isovaleric acid, mg/kg of DM | 3.62 | 4.64 | 3.34 | 4.51 | 1.143 | 0.86 | 0.36 | 0.95 |
| Valeric acid, mg/kg of DM | 3.18 | 1.54 | 1.12 | 0.97 | 0.521 | <0.01 | <0.01 | <0.01 |
| Aerobic stability, hours[2] | 150[b] | >240[a] | 205[a] | >240[a] | 10.9 | 0.03 | <0.01 | 0.03 |

[1] Probabilities for the effects of grain silage source (G), sodium benzoate (A) and the interaction between grain moisture content and sodium benzoate (G × A). Significant differences when $P \leq 0.05$ and trends when $P > 0.05$ and $< 0.10$. [2] Different lowercase letters within a row indicate significant statistical differences. DM = Dry Matter; Dmcorr = DM corrected for volatiles; WSC = Water-soluble carbohydrates.

**Table 3 Physical characteristics of high moisture corn silages (HMC) or reconstituted corn grain silages (RCG), without (CON) or with sodium benzoate (BEN).**

| Item | HMC | | RCG | | SEM | *P*-value[1] | | |
|---|---|---|---|---|---|---|---|---|
| | CON | BEN | CON | BEN | | G | A | A x G |
| Sieve[2], mm | | | | | | | | |
| 6.70 | 3.54 | 2.92 | 0.44 | 0.12 | 0.418 | <0.01 | 0.28 | 0.73 |
| 4.75 | 9.48 | 8.94 | 0.59 | 0.58 | 0.729 | <0.01 | 0.71 | 0.72 |
| 3.35 | 16.36 | 16.80 | 2.75 | 2.72 | 1.703 | <0.01 | 0.91 | 0.89 |
| 2.36 | 24.9 | 24.0 | 10.5 | 11.1 | 1.86 | <0.01 | 0.95 | 0.72 |
| 1.70 | 10.54 | 9.45 | 14.20 | 14.29 | 0.487 | <0.01 | 0.31 | 0.23 |
| 1.18 | 9.67 | 9.88 | 17.86 | 18.54 | 0.448 | <0.01 | 0.32 | 0.60 |
| 0.59 | 12.4 | 13.6 | 31.3 | 31.8 | 0.60 | <0.01 | 0.06 | 0.39 |
| Pan | 13.00 | 14.28 | 22.28 | 20.84 | 1.060 | <0.01 | 0.94 | 0.18 |
| Geometric mean particle size, µm | 1,953 | 1,866 | 1,124 | 1,142 | 71.8 | <0.01 | 0.63 | 0.47 |
| Surface area, sq cm/g | 25.5 | 26.2 | 32.1 | 31.7 | 0.57 | <0.01 | 0.74 | 0.28 |
| Grains < 4.75 mm, % | 86.8 | 88.1 | 98.9 | 99.3 | 0.97 | <0.01 | 0.42 | 0.65 |
| Grains < 1.18 mm, % | 25.4 | 27.9 | 53.6 | 52.7 | 1.43 | <0.01 | 0.50 | 0.14 |

[1] Probabilities for the effects of grain silage source (G), sodium benzoate (A) and the interaction between grain moisture content and sodium benzoate (G × A). Significant differences when $P \leq 0.05$ and trends when $P > 0.05$ and < 0.10. [2]Percentage of particles retained on each sieve (DM basis).

**Table 4 Apparent total-tract digestibility (n = 6 cows/treatment) of nutrients of high moisture corn silages (HMC) or reconstituted corn grain silages (RCG), without (CON) or with sodium benzoate (BEN).**

| Item | HMC | | RCG | | SEM | *P*-value[1] | | |
|---|---|---|---|---|---|---|---|---|
| | CON | BEN | CON | BEN | | G | A | A x G |
| Digestibility, % | | | | | | | | |
| Dry matter | 67.7 | 68.5 | 67.8 | 68.2 | 0.73 | 0.91 | 0.32 | 0.81 |
| Organic matter | 71.2 | 71.3 | 70.6 | 71.2 | 0.82 | 0.54 | 0.56 | 0.74 |
| Crude Protein | 69.2 | 68.6 | 68.4 | 68.3 | 1.02 | 0.52 | 0.66 | 0.79 |
| Neutral detergent fiber | 50.9 | 51.5 | 50.3 | 50.8 | 1.23 | 0.52 | 0.62 | 0.95 |
| Starch | 92.2 | 92.8 | 92.3 | 92.8 | 1.30 | 0.83 | 0.65 | 0.96 |
| Total digestible nutrients, % | 73.0 | 73.7 | 73.3 | 73.6 | 0.68 | 0.96 | 0.30 | 0.87 |

[1] Probabilities for the effects of grain silage source (G), sodium benzoate (A) and the interaction between grain moisture content and sodium benzoate (G × A). Significant differences when $P \leq 0.05$ and trends when $P > 0.05$ and < 0.10.

Sodium benzoate significantly reduced acetic acid (−19%), ethanol (−57%), 1,2-propanediol (−46%), 2,3-butanediol (-58%), propionic acid (−21%), ethyl lactate (−59%), and butyric acid (−62%) concentrations compared with control silages (P < 0.01; Table 2). Silage pH slightly increased with sodium benzoate (P = 0.01).

Rehydrated corn grain silage presented greater acetic acid concentration compared with HMC (P < 0.01) and tended to show greater butyric acid (P = 0.06). Aerobic stability was improved by sodium benzoate, particularly in HMC (P = 0.03).

### *3.2 Physical Characteristics*

Geometric mean particle size (GMPS) was greater for HMC compared with RCG (P < 0.01; Table 3). The proportion of particles below 4.75 mm was greater in RCG (P < 0.01), reflecting differences in processing method [21].

### *3.3 Apparent Total-Tract Digestibility*

Total-tract digestibility of DM, OM, CP, and NDF did not differ among treatments (Table 4). However, starch digestibility increased with sodium benzoate inclusion (P = 0.05). Grain source did not affect digestibility parameters.

*3.4 Intake and Milk Production*

Dry matter intake (DMI) was not affected by grain source or additive (Table 5). Milk yield increased by 0.8 kg $d^{-1}$ with sodium benzoate inclusion (P = 0.05). Fat-corrected milk showed a grain × additive interaction (P = 0.03). Protein yield tended to increase with sodium benzoate (P = 0.08). No differences were observed between HMC and RCG for milk yield or feed efficiency.

*3.5 Feeding Behavior*

Sodium benzoate increased rumination time (P < 0.01), ingestion time (P < 0.01), meal frequency (P = 0.01), and total chewing time (P = 0.02) compared with control diets (Table 6). Meal duration tended to be greater for RCG diets (P = 0.07).

**Table 5 Apparent total-tract digestibility (n = 6 cows/treatment) of nutrients of high moisture corn silages (HMC) or reconstituted corn grain silages (RCG), without (CON) or with sodium benzoate (BEN).**

| Item | HMC | | RCG | | SEM | *P*-value[1] | | |
|---|---|---|---|---|---|---|---|---|
| | CON | BEN | CON | BEN | | G | A | A x G |
| DMI, kg/d | 23.0 | 23.8 | 23.4 | 23.9 | 0.64 | 0.78 | 0.19 | 0.96 |
| Milk, kg/d | 30.8 | 31.9 | 31.4 | 31.9 | 0.64 | 0.20 | 0.05 | 0.18 |
| ECM, kg/d | 29.4 | 30.2 | 30.5 | 30.2 | 0.97 | 0.11 | 0.34 | 0.14 |
| FCM, kg/d (3.5%) | 29.0b | 30.6a | 30.4a | 30.2ab | 0.93 | 0.21 | 0.07 | 0.03 |
| Fat, % | 3.33 | 3.42 | 3.43 | 3.36 | 0.103 | 0.79 | 0.87 | 0.15 |
| Fat, kg/d | 1.031 | 1.087 | 1.080 | 1.064 | 0.0373 | 0.20 | 0.27 | 0.23 |
| Protein, % | 3.06 | 3.09 | 3.07 | 3.07 | 0.076 | 0.79 | 0.37 | 0.25 |
| Protein, kg/d | 0.943 | 0.979 | 0.967 | 0.971 | 0.0200 | 0.48 | 0.08 | 0.14 |
| Lactose, % | 4.55 | 4.57 | 4.57 | 4.57 | 0.031 | 0.64 | 0.57 | 0.62 |
| Lactose, kg/d | 1.398 | 1.449 | 1.443 | 1.451 | 0.0336 | 0.25 | 0.11 | 0.25 |
| Solids, % | 11.9 | 12.0 | 12.0 | 11.9 | 0.14 | 0.87 | 0.81 | 0.12 |
| Solids, kg/d | 3.661 | 3.820 | 3.800 | 3.787 | 0.1011 | 0.22 | 0.08 | 0.04 |
| MUN, mg/dL | 12.5 | 12.0 | 12.0 | 11.8 | 0.29 | 0.15 | 0.21 | 0.12 |
| Feed efficiency (FCM : DMI) | 1.27 | 1.28 | 1.29 | 1.26 | 0.038 | 0.81 | 0.74 | 0.59 |

[1] Probabilities for the effects of grain silage source (G), sodium benzoate (A) and the interaction between grain moisture content and sodium benzoate (G × A). Significant differences when $P \leq 0.05$ and trends when $P > 0.05$ and < 0.10. DMI = Dry Matter Intake; ECM = Energy Corrected Milk; MUN = Milk Urea Nitrogen; FCM = Fat Corrected Milk.

**Table 6 Feeding behavior of cows (n = 6 cows/treatment) fed diets with high moisture corn silages (HMC) or reconstituted corn grain silages (RCG), without (CON) or with sodium benzoate (BEN).**

| Item | HMC | | RCG | | SEM | *P*-value[1] | | |
|---|---|---|---|---|---|---|---|---|
| | CON | BEN | CON | BEN | | G | A | A x G |
| Fecal starch, % | 7.92 | 7.69 | 7.83 | 7.70 | 0.173 | 0.79 | 0.27 | 0.77 |
| Chewing behavior, min/d | | | | | | | | |
| Ingestion | 241 | 267 | 244 | 276 | 11.8 | 0.52 | <0.01 | 0.72 |
| Rumination | 537 | 587 | 569 | 582 | 17.6 | 0.34 | 0.03 | 0.23 |
| Chewing | 808 | 861 | 837 | 855 | 17.6 | 0.42 | 0.02 | 0.25 |
| Meals, /d | 6 | 7 | 6 | 7 | 0.3 | 0.95 | 0.01 | 0.59 |
| Meal duration, min | 36.4 | 38.3 | 39.2 | 41.2 | 1.51 | 0.07 | 0.20 | 0.98 |
| Particle sorting, %as fed | | | | | | | | |
| >19mm | 96.8 | 97.7 | 96.1 | 97.2 | 0.52 | 0.28 | 0.04 | 0.87 |
| 19-8mm | 100 | 100 | 100 | 100 | 0.4 | 0.12 | 0.42 | 0.59 |
| <8mm | 102 | 101 | 102 | 101 | 0.3 | 0.90 | 0.07 | 0.78 |

[1] Probabilities for the effects of grain silage source (G), sodium benzoate (A) and the interaction between grain moisture content and sodium benzoate (G × A). Significant differences when $P \leq 0.05$ and trends when $P > 0.05$ and < 0.10.

## 4. Discussion

### *4.1 Effects of Sodium Benzoate on Fermentation*

Sodium benzoate markedly reduced concentrations of ethanol, butyric acid, and secondary fermentation products, indicating inhibition of yeast and clostridial activity. The antimicrobial effect of benzoic acid is associated with the undissociated form penetrating microbial membranes and disrupting intracellular pH homeostasis [4].

The reduction in butyric acid suggests lower clostridial activity, which is desirable for improving silage stability and nutrient preservation. Similar reductions in undesirable fermentation end-products with benzoate have been reported in warm-climate silages [5, 6].

Although pH slightly increased, this response is consistent with reduced organic acid production and does not necessarily indicate impaired fermentation.

### *4.2 Starch Digestibility and Milk Yield*

Despite its antimicrobial action, sodium benzoate did not impair starch digestibility. Instead, total-tract starch digestibility increased [22]. This suggests that preservation of grain structure and reduced secondary fermentation may enhance nutrient availability.

Improved starch digestibility likely contributed to the observed increase in milk yield (+0.8 kg $d^{-1}$). Increased starch availability enhances ruminal propionate production and glucose supply for lactose synthesis, which drives milk yield [1].

The absence of DMI differences indicates that improved milk production was associated with enhanced nutrient utilization rather than increased intake.

### *4.3 HMC vs. RCG as Starch Sources*

Despite differences in fermentation profile and particle size distribution, no differences in milk production or digestibility were observed between HMC and RCG.

These results suggest that RCG is a viable alternative to HMC when moisture adjustment and processing are properly managed. The flexibility in harvest timing and storage logistics may represent a practical advantage for dairy systems [23].

### *4.4 Feeding Behavior Responses*

The increase in rumination and chewing time with sodium benzoate may reflect subtle modifications in silage physical structure or ruminal fermentation dynamics. Greater chewing activity may contribute to saliva production and ruminal buffering, potentially stabilizing ruminal pH. However, ruminal parameters were not substantially altered, indicating that behavioral changes were likely secondary to fermentation differences.

## 5. Conclusion

Rehydrated corn grain silage was equivalent to high moisture corn silage as a starch source for lactating dairy cows.

Sodium benzoate at 0.2% fresh matter:

- Reduced undesirable fermentation products
- Improved aerobic stability
- Increased total-tract starch digestibility
- Increased milk yield
- Altered feeding behavior

For a research perspective, sodium benzoate is a suitable additive for grain silages under tropical conditions.

## Acknowledgements

The authors gratefully acknowledge the financial support provided by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and the São Paulo Research Foundation (FAPESP), for the research grant provided to Luiz Gustavo Nussio. The authors also thank all staff and students involved in the experimental work for their valuable assistance.

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