Lactational response of early-lactation Holstein cows fed starch or floury corn silage

Ishwary P. Acharya¹ and David P. Casper^{2*}

¹Kay Dee Feed LLC, 1919 Grand Avenue, Sioux City, IA 51106

²Casper's Calf Ranch, 4890 West Lily Creek Road, Freeport, IL 61032

ABSTRACT

The study objective was to evaluate the lactational performance of early-lactation dairy cows fed a total mixed ration (TMR) based on corn silage produced from a standard starch hybrid compared with 2 floury starch hybrids. Twenty-one (6 primiparous and 21 multiparous) high-producing, early-lactation Holstein cows were blocked by calving date and parity and randomly assigned to 1 of 3 experimental corn silages from wk 4 through wk 12 postpartum using a randomized complete block design with wk 3 as a covariate. The Dekalb blend (STA; Monsanto Company, St. Louis, MO), Masters Choice 527 (LF₁; Masters Choice, Anna, IL), and Masters Choice 5250 (LF₂) treatments were planted and harvested as corn silage using a kernel processor silage harvester, inoculated, and ensiled in individual Ag-Bags (Ag-Bag, St. Nazianz, WI). The TMR were formulated to be isonitrogenous at 17.5% crude protein consisting of 15.9% alfalfa hay, 35.1% concentrate mix, and 48% of the respective experimental corn silage on a dry matter basis. Crude protein content of STA and LF₂ was lower than LF₁ corn silage. Starch content was higher for STA compared with LF₁ and LF₂ silage. The TMR digestible fiber (neutral detergent fiber) concentration was lower for STA than LF₁ and LF₂ (14.0, 15.5, and 17.9% dry matter for STA, LF₁, and LF₂, respectively). Growing crop year affected corn silage vomitoxin (0.60, 1.45, and 1.56 mg/kg) concentrations, which may have affected lactational performance as STA corn silage was from 2013, whereas LF₁ and LF₂ were from the 2012 crop year. Dry matter intake (22.9, 23.5, and 22.4 kg/d), milk yield (35.6, 34.8, and 36.1 kg/d), 3.5% fat-corrected milk yield (38.7, 36.5, and 37.6 kg/d), energy-corrected milk yield (38.2, 36.1, and 38.1 kg/d), feed efficiency (1.79, 1.61, and 1.67 kg/kg; 3.5% fat-corrected milk/dry matter intake), milk fat (4.17, 3.94, and 3.71%), milk protein (3.12, 3.09, and

3.03%), lactose (4.93, 4.92, and 4.92%), solids-not-fat (8.96, 8.92, and 8.85%), body weight change (−0.10, −0.06, and −0.08 kg/d), and body condition score change (−0.05, −0.04, and −0.05 score/d) were similar for early-lactation dairy cows fed all corn silage hybrids. Lower ruminal pH and acetate along with higher propionate molar percentages were reported for cows fed STA compared with cows fed LF₁ and LF₂. Early-lactation dairy cows fed a corn silage with lower starch and higher digestible fiber concentrations resulted in similar milk production compared with cows fed higher starch and lower digestible fiber concentrations.

Key words: corn silage, corn hybrid, high-producing dairy cow

INTRODUCTION

Whole-plant corn harvested as corn silage is a key forage component in many TMR fed to lactating dairy cows and continues to be a valuable and economical nutrient source (Ferraretto and Shaver, 2015). Corn silage is normally a high-energy forage with high yield potential on a per hectare basis compared with other forage crops. Various types of seed corn hybrids are available for growing and harvesting corn silage for feeding dairy cattle including waxy, high lysine, brown midrib (BMR), high oil, and leafy hybrids. Continuous selection of seed corn hybrids for corn silage has increasingly focused on improving NDF digestibility in addition to high grain content and overall DM yield (Nennich et al., 2003). A survey of the published literature found several studies that compared different corn silage hybrids on dairy cattle performance (Barriere et al., 1995; Oba and Allen, 1999; Kuehn et al., 1999; Bal et al., 2000; Ballard et al., 2001; Thomas et al., 2001; Clark et al., 2002; Ferraretto and Shaver, 2015). The BMR trait has consistently demonstrated an improvement in milk production (Oba and Allen, 1999; Bal et al., 2000; Ballard et al., 2001; Ferraretto and Shaver, 2015) among the evaluated corn silage hybrids. The leafy gene results in a corn plant with 8 or more leaves about the top ear that are lower in lignin with

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*Corresponding author: david.casper10@jcwifi.com

thicker, more digestible stalks, and the starch structure is more floury than vitreous. Most studies have shown little or no changes in milk yield when leafy corn silage hybrids were fed to lactating dairy cows (Kuehn et al., 1999; Bal et al., 2000; Ballard et al., 2001). However, research conducted by Thomas et al. (2001) and Clark et al. (2002) reported higher milk production while feeding leafy corn silage hybrids compared with conventional corn silage hybrids. The feeding of leafy corn silage hybrids in the TMR to dairy cows often resulted in similar DMI compared with the TMR containing conventional corn hybrids (Kuehn et al., 1999; Bal et al., 2000; Thomas et al., 2001; Ferraretto and Shaver, 2015). However, Ballard et al. (2001) and Clark et al. (2002) reported higher DMI by lactating dairy cows when offered a leafy corn silage hybrid compared with a conventional corn silage hybrid.

Although past research has not demonstrated a consistent response in milk production, DMI, or both from feeding a particular seed corn silage hybrid, new seed corn silage hybrids are introduced every year in the marketplace. With the release of new seed corn hybrids, it is essential to evaluate their agronomic traits, as well as their response to maintain or enhance dairy cattle performance. Masters Choice (Anna, IL) has developed MC 527 (LF₁) and MC 5250 (LF₂) as 2 new seed corn silage hybrids that have a floury starch structure (Casper et al., 2017) and higher digestible fiber compared with traditional seed corn hybrids that are high in flinty starch and lower digestible fiber (Kleinjan et al., 2017). These seed corn hybrids have demonstrated increased corn silage yield, higher sugar concentrations, higher digestible fiber, and greater starch digestibilities (Kleinjan et al., 2017) compared with standard silage hybrids, which is speculated to an altered ratio of ether and ester linkages among lignin and fiber carbohydrates (Raffrenato et al., 2017). We hypothesized that feeding these 2 new seed corn silage hybrids (LF₁ and LF₂) will supply more digestible energy as fiber and starch to enhance milk production compared with feeding a conventional starch corn silage hybrid. Therefore, the study objectives were to evaluate 2 floury corn hybrids, MC 527 (LF₁) and MC 5250 (LF₂), harvested for corn silage against conventional corn silage hybrid (STA) silage for nutrient composition, DMI, digestibility, and lactational performance of early-lactation dairy cows.

MATERIALS AND METHODS

Corn Planting, Harvest, and Corn Silage Production

Three different corn silage hybrids, STA (a blend of Dekalb Brand Seed including DKC48–12 RIB Brand Blend, DKC 52–29 RIB Brand Blend, and DKC 53–78

RIB Brand Blend, Monsanto Company, St. Louis, MO), MC 527 (LF₁; 105 d maturity, Masters Choice Seed Corn), and MC 5250 (LF₂; 102 d maturity, Masters Choice Seed Corn), were planted at the South Dakota State University Dairy Research and Training Facility in Brookings according to their recommended seeding rates of 86,487/ha and common agronomic practices. Fields were fertilized according to soil report recommendations and cultivated before planting. The LF₁ and LF₂ corn silage hybrids were grown and harvested during the 2012 crop year and STA corn silage was grown and harvested during the 2013 crop year. Corn silage was harvested at recommended maturity days of respective experimental varieties with a John Deere 6750 self-propelled forage harvester (John Deere, Moline, IL) set to a 1.9 cm theoretical length of cut with a kernel processor. After harvesting, corn silage was treated with *Lactobacillus* inoculant (Silo-King Plus, Agri-King Inc., Fulton, IL), ensiled in an Ag-Bag (Ag-Bag, St. Nazianz, WI), and allowed to ferment followed by storage until fed. The storage times were approximately 4, 14, and 14 mo for STA, LF₁, and LF₂ corn silages, respectively.

Lactating Dairy Cows, Rations, and Experimental Design

This lactation study was conducted at the Dairy Research and Training Facility during the winter of 2013–2014. All lactating dairy cows were cared for and managed according to South Dakota State University Institutional Animal Care and Usage Committee recommendations. Cows were housed in a freestall barn and fed a covariate diet (control starch) as a TMR immediately after calving using the Calan Broadbent feeder door and box system (American Calan Inc., Northwood, NH). Cows remained on the covariate ration from calving through the third week postpartum, after which they were randomly assigned to 1 of 3 dietary treatments if they were healthy and normal (i.e., no transition problems). Cows were blocked by calving date and parity using a randomized complete block design. Thirty (9 primiparous and 21 multiparous) high-producing, early-lactation Holstein cows were randomly selected and fed 1 of 3 experimental corn silages harvested from the planting of 3 different seed corn hybrids from wk 4 through wk 12 postpartum. However, only 21 cows (6 primiparous and 15 multiparous) completed the 12-wk feeding study because of exhausting the supply of the experimental corn silages.

Cows were fed individually their assigned diets once a day at 0600 h using a Calan Super Data Ranger (American Calan Inc.) to allow for 5 to 10% refusals. The diets were fed as a TMR and contained similar

ingredients in equal proportion, except the type of corn silage. All diets contained 63.9% forage (24.9% alfalfa hay and 75.1% corn silage) and 36.1% concentrate (Table 1) on a DM basis. Diets were formulated to be approximately 17.5% CP, 24.5% starch, 33.9% NDF, 20.1% ADF, and 5.6% ether extract, and were equal in estimated NE_L at 1.61 Mcal/kg of DM with all other nutrients formulated to meet or exceed nutrient requirements according to the NRC (2001) for a cow weighing 682 kg, producing 41 kg of milk with 3.7% fat and 3.1% protein. Agricultural Modeling and Training Systems software (AMTS LLC, Groton, NY) was used to formulate the TMR. Ration formulation and ingredient proportions were exactly the same among treatments except for the type or source of the experimental corn silage. Monensin and recombinant bST (Rumensin and rbST, Elanco Animal Health, Greenfield, IN) were not used in this study. Cows were milked 3 times daily at 0700, 1500, and 2200 h with milk production recorded electronically (Delaval-Alpro, Kansas City, MO) at each individual milking.

Body weight was electronically recorded using a digital livestock scale (model AWB-5K-SYS, Triner Scale and Manufacturing Company Inc., Olive Branch, MS) after morning milking between 0800 and 0900 h and BCS were taken at the end of every week including the covariate period. The BCS were recorded independently by 3 experienced individuals at the start of the study (covariate) and at the end of each week. The BCS were taken by using a scale of 1 to 5, with 5 being obese and 1 being emaciated as described by Wildman et al. (1982) and Edmonson et al. (1989).

Sample Collections

Individual ingredients, concentrate mix, TMR, and orts samples were taken weekly, composited by month, and subsamples were submitted to 2 different commercial laboratories for analysis of nutrient concentrations. Corn silage and hay samples were checked for DM on a weekly basis, and rations were adjusted to maintain ingredients at constant DM percentages. Samples of TMR were taken weekly to measure particle size using the Penn State Particle Separator (PSPS; Kononoff et al., 2003). The amounts of particles retained on the different screens were weighed and recorded.

Milk samples were collected at all 3 milking times once weekly. Milk samples were composited on a percentage by milk yield basis and sent to Heart of America DHI laboratory (Manhattan, KS) for compositional and quality analysis using AOAC International (2016) approved methods.

Rumen fluid samples were collected via an esophageal tube fitted with a suction strainer and hand operated

Table 1. Ingredient composition of experimental diets

Diet ingredient	Experimental diet ¹		
	STA	LF ₁	LF ₂
Starch corn silage	48.0	—	—
LF ₁ corn silage	—	48.0	—
LF ₂ corn silage	—	—	48.0
Alfalfa hay	15.9	15.9	15.9
Ground corn	11.6	11.6	11.6
Soybean meal	0.97	0.97	0.97
Distillers grain with solubles	6.77	6.77	6.77
Corn gluten meal	1.39	1.39	1.39
Whole cottonseed	7.74	7.74	7.74
Blood meal	0.35	0.35	0.35
Heat-treated soybean meal with lysine ²	2.90	2.90	2.90
Rumen bypass methionine ³	0.11	0.11	0.11
Rumen bypass lysine ⁴	0.15	0.15	0.15
Urea	0.48	0.48	0.48
Energy booster 100 ⁵	0.77	0.77	0.77
Limestone	1.43	1.43	1.43
Sodium phosphate monohydrate	0.23	0.23	0.23
Sodium bicarbonate	0.28	0.28	0.28
Magnesium oxide	0.09	0.09	0.09
Potassium magnesium sulfate	0.19	0.19	0.19
Potassium chloride white	0.10	0.10	0.10
Salt white	0.35	0.35	0.35
Selenium yeast ⁶	0.01	0.01	0.01
Mineral vitamin premix ⁷	0.19	0.19	0.19
Total	100.00	100.00	100.00

¹STA = diet with Dekalb blend corn silage (Monsanto Company, St. Louis, MO); LF₁ = diet with Masters Choice 527 corn silage (Masters Choice, Anna, IL); LF₂ = diet with Masters Choice 5250 corn silage.

²Soybest Pearl, Grain States Soya, West Point, NE.

³Meti Pearl, Kemin Industries, Des Moines, IA.

⁴Lysi Pearl, Kemin Industries.

⁵Energy booster 100, Milk Specialties Global, Eden Prairie, MN.

⁶Mixture of organic selenium yeast and brewers dried yeast, Sel-Plex 2000 (Alltech Inc., Brookings, SD).

⁷10% magnesium, 2.5% zinc, 1.9% manganese, 325 mg/kg cobalt, 5,830 mg/kg copper, 325 mg/kg iodine, 1,515 mg/kg selenium, 544.32 kIU/kg vitamin A, 186.86 kIU/kg vitamin D₃, 2.18 kIU/kg vitamin E.

pump on one day during wk 3, 6, and 9 of the experimental period approximately 3 h after feeding. The first 100 mL of rumen fluid was discarded to minimize saliva contamination. After collection, rumen fluid was mixed thoroughly and pH was measured immediately using an electronic pH meter (Corning 350, Corning Inc., Corning, NY). If the rumen fluid collected was at a pH >7.0, rumen fluid was discarded and additional rumen fluid was collected to ensure minimal saliva contamination. Two 10-mL samples of rumen fluid were collected, where one 10-mL sample was added to a vial containing 200 μ L of 50% (vol/vol) H₂SO₄ for later determination of NH₃-N and the other 10-mL sample was added to a vial containing 2 mL of 25% (wt/vol) metaphosphoric acid for later determination of VFA. After sample collection and preparation, rumen fluid samples were immediately stored at -20°C for further analysis.

Sample Analyses

Feed samples (TMR, concentrate mix, and individual ingredients) were composited by month and dried at 55°C for 48 h in a forced-air oven (style V-23, Despatch Oven Co., Minneapolis, MN). Composites of feed samples were ground to a 4 mm particle size (Wiley mill, Arthur H. Thomas Co., Philadelphia, PA), and then further ground to a 1-mm particle size using an ultracentrifuge mill (Brinkman Instruments Co., Westbury, NY) before being sent to Analab (Fulton, IL) for DM and nutrient analysis. Samples were analyzed using the following AOAC International (2016) methods: DM (935.29), CP (990.03), NDF with amylase (2002.04, without sulfite), ADF (973.18, not in sequence), ADIN (973.18 and 976.06), neutral detergent insoluble protein (2002.04, without sulfite and 976.06), lignin (973.18), ash (942.05 and Undersander et al., 1993), Ca (985.01), P (985.01), Mg (985.01), K (985.01), Na (985.01), Cl (915.01), S (923.01), and pH (981.12). The remaining nutrients parameters were measured using the following methods: soluble protein (Krishnamoorthy et al., 1982), starch (Glucose Reagent Set, Amresco, Solon, OH; Alpkem Corporation, Portland, OR), oil/fat (Damon, 1966), in vitro DM digestibility [24-h ruminal and 24-h enzymatic digestion using the Kansas State Buffer (Marten and Barnes, 1980)], NDF digestibility [NDFd; Van Soest et al., 1991, incubated for 30 h using the Kansas State Buffer (Marten and Barnes, 1980)], lactic acid (El Rassi, 1996), acetic acid (Cancalon, 1993), NFC calculated using assay results (NRC, 2001), NE_L calculated from assay results including NDFd and lignin (NRC, 2001), and vomitoxin (ELISA test kit, Neogen Corporation, Lansing, MI). In addition, the DM composition of forages and grain mix was determined weekly by drying in a 105°C forced-air oven (Despatch LEVBI-75, Despatch Industries, Minneapolis, MN).

The monthly composites of each experimental corn silage were subsampled and submitted to Rock River Laboratory Inc. (Watertown, WI) for nutrient analyses. Samples were also analyzed for CP, soluble protein, neutral detergent insoluble crude protein, acid detergent insoluble crude protein (**ADICP**), available CP calculated as CP minus ADICP, NDF, fat, lignin, starch, ash, pH, lactic acid, and acetic acid using standard AOAC International (2016) methods as described previously. However, additional analyses of undigested NDF at 30, 120, and 240 h (Raffrenato, et al., 2018), total-tract NDF digestibility (Goeser and Combs, 2009), dynamic NDF digestion rate (**k_d**; Goeser and Combs, 2009), soluble starch (Akerlind, et al., 2011), 7-h in vitro starch digestion (Richards, et al., 1995), and ammonia were conducted to provide additional characterization of the experimental corn silages.

The composition of milk fat, protein, and lactose of composited milk samples were analyzed via near-infrared spectroscopy (Bentley 2000 Mid-Infrared Milk Analyzer, Bentley Instruments, Chaska, MN). The MUN concentration was determined using a chemical method based on a modified Berthelot reaction (Chaney and Marbach, 1962; ChemSpec 150 Analyzer, Bentley Instruments). Somatic cell counts were determined with a flow cytometer laser (Somacount 500, Bentley Instruments). Energy-corrected milk was calculated using the equation $[(0.327 \times \text{kg of milk}) + (12.95 \times \text{kg of fat}) + (7.20 \times \text{kg of protein})]$, and 3.5% FCM was calculated using the equation $(0.4324 \times \text{kg of milk}) + (16.216 \times \text{kg of milk fat})$, as described by Orth (1992).

Rumen fluid samples were thawed and centrifuged at $30,000 \times g$ for 20 min at 20°C (Eppendorf 5403, Eppendorf North America, Hauppauge, NY). Rumen fluid samples that were preserved in 50% H₂SO₄ were analyzed for rumen NH₃-N concentrations as described by Chaney and Marbach (1962) and Weatherburn (1967). Rumen fluid samples preserved in 25% metaphosphoric acid were analyzed for VFA concentrations using a gas chromatograph (model 6890, Hewlett-Packard, Palo Alto, CA) with a flame ionization detector. The injector port temperature was set at 250°C with an injection split ratio of 30:1. The VFA were separated on a capillary column (15 m $\times$ 0.25 mm i.d.; Nukol, 17926-01C, Supelco Inc., Bellefonte, PA) with a flow rate 1.3 mL/min of He using 2-ethylbutyrate as an internal standard. The column and detector temperatures were maintained at 140 and 250°C, respectively.

Statistical Analyses

All data were checked for normality and outliers using the Univariate procedure of SAS (version 9.4, SAS Institute Inc., Cary, NC) before any statistical analyses were conducted. Box and whisker plots and the Shapiro-Wilk test were used to verify that data were normality distributed ($P > 0.10$). All data (milk production, composition, feed intake, and so on) were then subjected to least squares ANOVA for a randomized complete block design (Steele and Torrie, 1980) using the MIXED procedure of SAS having 3 corn silage dietary treatments and 7 blocks or replicates. The statistical model used was

$$Y_{ijk} = \mu + \text{Rep}_i + T_j + W_k + (T_j \times W_k) + \text{Cov} + e_{ijk},$$

where Y_{ijk} = the dependent variable, μ = the overall mean, Rep_i = the replication or block, T_j = the treatment (experimental corn silage), W_k = the study

week, $T_j \times W_k$ = the interaction of treatment by study week, Cov = the covariate, and e_{ijk} = the random error. Cows were blocked according to calving date and parity (2 primiparous vs. 5 multiparous/treatment). Due to parity being nested within Rep, it was found to be nonsignificant ($P > 0.15$) and therefore deleted from the statistical model. The individual cow data from the covariate week (3rd week postpartum) were included in the model. Treatment, week, and treatment $\times$ week interactions were considered fixed effects with Rep/block as a random effect. Least squares covariate adjusted means were separated by the PDIF statement. The PDIF statement is the least significant difference method, which was used to compare treatment means when the ANOVA F -test was significant. The monthly composites of experimental corn silages and TMR were statistically analyzed using the PROC MIXED procedure as a completely random design having 6 observations per treatment. Treatment was considered a fixed effect in the model. All results are reported as least squares means. Differences among treatments were considered significant at $P < 0.05$ and trends at $0.05 < P \leq 0.10$.

RESULTS AND DISCUSSION

Cropping Seasons

The 2012 crop growing season was drier and hotter than normal, but the 2013 crop growing season was closer to normal (Table 2), when considering the historical average temperature and precipitation for the past 30 yr. Thus, the experimental corn silages harvested during the 2012 growing season (LF₁ and LF₂) were

drought stressed due to high temperatures and lack of rainfall compared with corn silage produced in the 2013 crop season (STA). The temperature and rainfall during the major corn growing months of June, July, and August was +5.4°C and −130.4 mm rain versus +0.3°C and 14.4 mm rain for 2012 and 2013, respectively, compared with historical averages. Drought-stressed corn silage can be higher in CP and some minerals (Ca and K), along with decreased energy concentrations (Roth, 2012). Corn silage potentially may have higher NDF (fiber) with a higher NDF digestibility and decreased grain (little to no starch content) depending on the drought severity (Roth, 2012). To our knowledge, side-by-side comparisons of drought-stress and non-drought-stress corn silage hybrids are not available in the literature and rations need to be balanced for nutrient availability whether drought-stress or not. The 2012 drought was among one of the most severe agricultural droughts in the history of the United States (USDA, 2013). Crop production data were not recorded because the fields were not replicated. The differences in crop growing years between corn silage hybrids was an unplanned occurrence that affected storage times between the corn silage hybrids, which could have an effect on starch digestibility (Ferraretto, 2017). The effect of storage time differences will be discussed later.

Nutrient Composition of Experimental Rations

The ingredients and their proportion used to formulate the different experimental rations are presented in Table 1. The control (STA) ration was used as the covariate diet. All experimental diets were similar in ingredient proportions and differed only in the type

Table 2. Climatic conditions during the 2012 and 2013 corn growing seasons¹

Month and year	Temperature, °C		Precipitation, mm	
	Mean	Deviation ²	Total	Deviation ²
April 2012	9.4	3.0	70.4	14.1
May 2012	15.6	2.2	176.3	96.3
June 2012	20.6	1.8	40.4	−69.8
July 2012	25.0	3.7	35.6	−47.6
August 2012	20.0	−0.1	63.0	−13.0
September 2012	15.0	0.1	18.5	−61.9
October 2012	6.1	−1.5	64.8	14.3
November 2012	0.6	1.4	11.4	−10.8
April 2013	1.1	−5.5	66.3	8.9
May 2013	12.8	−0.6	77.5	−4.7
June 2013	18.3	−0.5	149.4	39.7
July 2013	21.1	−0.3	91.9	12.3
August 2013	21.1	1.1	38.9	−37.6
September 2013	18.3	3.4	66.8	−11.9
October 2013	7.8	0.2	58.4	9.3
November 2013	−1.7	−0.9	10.2	−11.0

¹Data collected from South Dakota State University weather station approximately 3 km from the fields.

²Deviation = actual minus 30-yr monthly average.

of corn silage incorporated. Chemical composition of individual ingredients and final experimental diets are presented in Table 3. Corn silage produced from LF₁ hybrid was higher in CP concentration compared with STA and LF₂ hybrids. The vomitoxin concentration (mg/kg) was higher ($P < 0.05$) for LF₁ and LF₂ compared with STA silage, which might be associated with differences between the crop growing seasons (i.e., 2012 vs. 2013). The 2012 crop growing year was hotter and drier for producing the LF₁ and LF₂ corn silages compared with the 2013 crop growing year, which produced the control STA corn silage. Diaz et al. (2001) reported that lactating dairy cows consuming 2.5 mg/kg vomitoxin in the total ration demonstrated reduced milk production with even lower vomitoxin concentrations being implicated in reducing lactation performance. Although the goal was to balance CP concentrations at approximately 17.5%, the final experimental rations were a little higher than expected. The control STA ration was approximately 0.5% lower in CP concentration compared with LF₁ and LF₂ rations, which was the result of higher CP concentrations of the LF₁ and LF₂ experimental corn silages, and the initial rations were formulated based on the STA corn silage nutrient concentrations. Ferraretto and Shaver (2015) reported that highly digestible fiber corn silage hybrids are greater in CP concentrations than conventional hybrids.

Total dietary NDF content was higher ($P < 0.05$) in LF₂ followed by LF₁ and STA. Lignin content of LF₁ and LF₂ diets were higher ($P < 0.05$) compared with the STA diets, which follows the trend of lignin as in silages. Starch content was higher ($P < 0.05$) in the STA diet followed by LF₁ and LF₂ as expected. Sugar content of LF₁ and LF₂ diets were higher ($P < 0.05$) compared with STA diet, due to higher sugar concentrations in the LF₁ and LF₂ corn silages. The NDFd was higher ($P < 0.05$) for LF₂ diets compared with the STA diet, with LF₁ being intermediate. Although some differences were observed between the diets in macromineral concentrations, we did not expect any variation in lactational performance because all values were close or slightly higher than mineral requirements as suggested by NRC (2001).

Chemical composition of experimental silages analyzed at a 2nd laboratory to obtain additional analytical information for silage characterization (Rock River Laboratory Inc.) reported higher ($P < 0.05$) CP and available CP in LF₁ silage, LF₂ being intermediate, and STA silage being the lowest (Table 4). However, higher ($P < 0.05$) soluble protein concentrations were reported for STA corn silage compared with LF₁ and LF₂ silage, which is in contrast to the corn silage hybrid summary of Ferraretto and Shaver (2015). Neutral detergent insoluble crude protein was higher ($P <$

0.05) for LF₁ and LF₂ silage compared with STA, but ADICP was similar ($P > 0.05$) among experimental silages. The NDF content was higher ($P < 0.05$) for LF₂ than LF₁ but STA was intermediate. Undigestible NDF at 30 h was similar ($P > 0.05$) among the experimental silages. However, undigestible NDF at 120 and 240 h were higher ($P < 0.05$) for LF₂ silage compared with STA and LF₁ silage. The TTNDF and NDF k_d were similar ($P > 0.05$) among the experimental silages. Total starch content was higher ($P < 0.05$) for STA silage compared with LF₁ and LF₂ silage as expected. Soluble starch value and 7-h starch digestibility were higher ($P < 0.05$) for LF₁ silage compared with STA with LF₂ being intermediate. The greater amylopectin concentration resulting in less vitreous of the starch fractions for LF₁ and LF₂ would be expected to result in greater 7 h in vitro starch digestion (Giuberti et al., 2014; Casper et al., 2017). Nennich et al. (2003) compared conventional corn silage hybrids with 2 leafy corn silage hybrids and reported similar starch digestibility while feeding to lactating dairy cows. Ferraretto et al. (2015) also reported greater in vivo starch digestibility for leafy floury corn silage compared with BMR silage. In contrast, Morrison et al. (2014) reported similar starch digestibility for leafy starch and BMR silage diets. The other possible confounding factor to consider is that LF₁ and LF₂ silages were stored for over a year and storage time has been shown to result in increasing corn silage starch digestibility with storage time (Ferraretto, 2017). Total sugar content value was double in LF₁ and LF₂ silage compared with STA. Whole plant sugar concentrations were higher for LF₁ and LF₂ hybrids in corn silage variety trials (Kleinjan et al., 2017). However, experimental silages were similar in terms of fat, lignin, and ash content. Lactic acid concentration was higher ($P < 0.05$) in STA silage, whereas ammonia concentration was higher ($P < 0.05$) in LF₁ and LF₂.

TMR Particle Size Distributions

The percentage of TMR particles on the upper, middle, and lower sieve and bottom pan of the PSPS (Table 5) exhibited small, but significant differences ($P < 0.10$ or $P < 0.05$). Cows fed LF₁ and LF₂ TMR were higher ($P < 0.05$) in particles retained on the upper sieve compared with cows fed the STA TMR (Table 5). Since all values from PSPS screens were within the recommended ranges (Heinrichs and Kononoff, 2002; Kononoff et al., 2003) and the differences were rather small between treatments, the expectation would be that TMR particle size would not influence lactational performance due to TMR particle size variations. The data are supplied to support that conclusion.

Table 3. Nutrient composition of individual forages, feed ingredients, grain mix, and TMR¹

Nutrient composition	Corn silage ²										TMR ²						
	GC	BM	WCS	CGM	DG	SBM	SBP	GM	AH	STA	LF ₁	LF ₂	SEM	STA	LF ₁	LF ₂	SEM
DM, %	89.3	90.9	92.0	91.2	90.5	90.0	90.2	90.2	86.3	38.0 ^c	39.4 ^b	42.1 ^a	0.73	53.9 ^b	55.3 ^b	57.7 ^a	0.86
% of DM unless noted																	
CP	9.30	94.7	24.1	73.4	32.8	52.5	49.5	25.5	21.0	8.02 ^b	9.35 ^a	8.28 ^b	0.30	17.7 ^b	18.3 ^a	18.3 ^a	0.17
SP, % of CP	—	—	—	10.6	19.9	—	—	33.9	33.6	53.8 ^a	51.7 ^{ab}	48.1 ^b	1.84	40.6 ^a	39.5 ^{ab}	38.2 ^b	0.87
NDF	—	—	44.9	—	29.6	—	—	18.0	42.1	36.3	38.2	37.8	0.90	28.4 ^b	30.3 ^b	32.7 ^a	0.81
ADF	—	—	34.3	4.99	13.7	—	—	15.3	32.8	21.5 ^f	22.6 ^{ef}	23.1 ^e	0.69	19.1 ^b	20.3 ^{ab}	21.5 ^a	0.61
Lignin	—	—	—	—	—	—	—	—	6.80	1.80 ^b	2.19 ^a	2.41 ^a	0.13	2.72 ^c	3.22 ^b	3.81 ^a	0.18
Starch	70.6	—	—	14.0	7.79	—	—	24.6	—	37.0 ^a	32.4 ^b	33.3 ^{ab}	0.97	26.3 ^a	23.5 ^b	23.6 ^b	0.56
NFC	—	—	—	—	24.7	—	—	38.2	28.5	49.8 ^a	46.7 ^b	47.4 ^a	1.08	43.0 ^a	40.7 ^b	38.6 ^b	0.86
NE _L , Mcal/kg	2.01	—	—	—	—	1.90	—	—	1.43	1.72 ^e	1.68 ^{ef}	1.65 ^f	0.01	1.76 ^a	1.74 ^{ab}	1.70 ^b	0.01
Sugar	1.71	—	—	—	—	9.34	—	—	4.58	0.25 ^b	0.93 ^a	0.99 ^a	0.09	1.86 ^b	2.68 ^a	2.30 ^a	0.14
Ether extract	3.62	—	—	2.40	9.84	—	6.17	9.33	1.04	2.69	2.45	2.51	0.07	4.76	4.73	4.84	0.07
Ash	—	—	—	—	4.93	—	—	11.6	9.99	3.84 ^b	4.41 ^a	4.89 ^a	0.19	7.18	7.20	7.04	0.22
IVDMD	—	—	—	—	—	—	—	—	67.7	72.2 ^{ef}	73.2 ^c	71.7 ^c	0.60	81.1 ^a	79.1 ^b	78.6 ^b	0.60
NDFd	—	—	—	—	—	—	—	—	35.8	49.1	51.7	48.1	0.88	49.2 ^c	51.3 ^b	54.8 ^a	0.71
Ca	—	0.04	0.15	0.04	0.04	0.30	0.32	1.55	1.41	0.23 ^b	0.27 ^a	0.26 ^{ab}	0.02	0.85	0.88	0.84	0.03
P	0.25	0.12	0.68	0.46	0.70	0.71	0.59	0.61	0.29	0.21 ^b	0.25 ^a	0.26 ^a	0.01	0.36 ^b	0.39 ^a	0.40 ^a	0.01
Mg	0.12	0.02	0.42	0.05	0.31	0.30	0.27	0.41	0.42	0.20 ^c	0.23 ^b	0.26 ^b	0.01	0.30 ^c	0.32 ^b	0.35 ^a	0.01
K	—	0.39	1.25	0.16	1.03	—	2.02	1.08	1.88	0.74 ^b	0.94 ^a	0.85 ^a	0.03	1.11 ^b	1.21 ^a	1.21 ^a	0.02
Na	0.07	0.23	0.01	0.03	0.20	0.01	—	0.78	0.13	0.03	0.03	0.03	<0.01	0.28 ^b	0.28 ^{ab}	0.29 ^a	0.01
Cl	—	—	—	—	—	—	—	0.80	0.64	0.19 ^b	0.38 ^a	0.40 ^a	0.02	0.53 ^b	0.61 ^a	0.63 ^a	0.01
S	0.09	0.45	0.28	0.97	0.61	0.41	0.39	0.47	0.25	0.06 ^b	0.08 ^a	0.09 ^a	<0.01	0.28	0.28	0.30	0.01
pH, value	—	—	—	—	—	—	—	—	—	4.03 ^b	4.20 ^a	4.16 ^{ab}	0.08	—	—	—	—
Lactic acid	—	—	—	—	—	—	—	—	—	5.43 ^a	3.72 ^b	3.40 ^b	0.32	—	—	—	—
Acetic acid	—	—	—	—	—	—	—	—	—	1.91 ^{ef}	2.09 ^e	1.19 ^f	0.34	—	—	—	—
Vomitoxin, mg/kg	—	—	—	—	—	—	—	—	—	0.60 ^b	1.45 ^a	1.56 ^a	0.10	—	—	—	—

^{a-c}Least squares means within the same row with different superscripts differ ($P < 0.05$).^dLeast squares means within the same row with different superscripts differ ($P < 0.10$).¹GC = ground corn; BM = blood meal; WCS = whole cottonseed; CGM = corn gluten meal; DG = distillers grain; SBM = soybean meal; SBP = Soybest Pearl (Grain States Soya, West Point, NE); GM = grain mix; AH = alfalfa hay; SP = soluble protein; IVDMD = in vitro dry matter digestibility; NDFd = 30 h in vitro neutral detergent fiber digestibility.²STA = Dekalb blend corn silage (Monsanto Company, St. Louis, MO); LF₁ = Masters Choice 527 corn silage (Masters Choice, Anna, IL); LF₂ = Masters Choice 5250 corn silage.

Table 4. Nutrient composition (% of DM) of experimental corn silages¹

Nutrient composition ²	Experimental corn silage ³			SEM	<i>P</i> <	
	STA	LF ₁	LF ₂		Treatment ⁴	
CP	7.41 ^c	8.67 ^a	8.30 ^b	0.13	0.01	
Available CP	6.75 ^c	7.99 ^a	7.61 ^b	0.12	0.01	
SP, % of CP	60.3 ^a	53.8 ^b	53.3 ^b	1.18	0.04	
NDICP	0.48 ^b	0.60 ^a	0.69 ^a	0.03	0.01	
ADICP	0.66	0.67	0.69	0.02	0.64	
NDF	38.3 ^{ab}	38.1 ^b	39.2 ^a	0.51	0.11	
uNDF ₃₀	24.6	23.9	24.6	0.43	0.31	
uNDF ₁₂₀	11.1 ^b	11.5 ^b	12.5 ^a	0.19	0.01	
uNDF ₂₄₀	10.7 ^b	11.3 ^b	11.9 ^a	0.27	0.06	
TTNDFD, % of NDF	41.6	40.5	39.6	0.67	0.37	
Dynamic NDF k _d , %/h	4.41	4.39	4.31	0.10	0.85	
Starch	35.9 ^a	33.7 ^b	33.3 ^b	0.63	0.07	
Soluble starch, % of starch	34.3 ^b	39.9 ^a	35.6 ^{ab}	1.62	0.06	
7-h starch digestion, % of starch	68.4 ^c	77.9 ^a	73.0 ^b	1.22	0.01	
Sugar	1.06 ^b	2.23 ^a	2.07 ^a	0.20	0.02	
Fat	2.47	2.46	2.45	0.05	0.96	
Lignin	2.08	2.17	2.50	0.16	0.40	
Ash	4.38	4.54	4.35	0.08	0.29	
pH	4.67 ^b	5.17 ^a	5.19 ^a	0.06	0.01	
Lactic acid	5.23 ^a	2.68 ^b	2.36 ^b	0.34	0.01	
Acetic acid	2.27	2.64	2.34	0.22	0.35	
Ammonia nitrogen	0.07 ^b	0.10 ^a	0.09 ^a	<0.01	0.01	

^{a-c}Least squares means within the same row with different superscripts differ ($P < 0.05$).

¹Rock River Laboratory Inc., Watertown, WI.

²SP = soluble protein; NDICP = neutral detergent fiber insoluble crude protein; ADICP = acid detergent fiber insoluble crude protein; uNDF₃₀ = undigestible neutral detergent fiber at 30 h; uNDF₁₂₀ = undigestible neutral detergent fiber at 120 h; uNDF₂₄₀ = undigestible neutral detergent fiber at 240 h; TTNDFD = total-tract neutral detergent fiber digestibility; k_d = digestion rate.

³STA = Dekalb blend corn silage (Monsanto Company, St. Louis, MO); LF₁ = Masters Choice 527 corn silage (Masters Choice, Anna, IL); LF₂ = Masters Choice 5250 corn silage.

⁴Probability of *F*-test for treatment.

DMI

Dry matter intake was similar ($P > 0.10$) among lactating cows fed the treatment diets containing the experimental corn silages (Table 6). Correspondingly, Kuehn et al. (1999), Thomas et al. (2001), and Nennich et al. (2003) reported similar DMI between rations containing conventional and leafy corn silage hybrids.

In contrast, Clark et al. (2002) reported 0.9 kg/d higher DMI for cows fed a ration containing a leafy hybrid corn silage compared with a conventional corn silage hybrid. Hassanat et al. (2017) also reported higher DMI when cows were fed a BMR silage-based diet compared with a conventional corn silage-based diet. Ferraretto and Shaver (2015) in their meta-analysis demonstrated that high NDF digestibility corn silage hybrids enhanced

Table 5. Total mixed ration particle size distribution (%) as measured by Penn State Particle Size Separator (PSPS; Kononoff et al., 2003) on an as-fed basis

PSPS screen size (mm)	Treatment ¹			SEM	<i>P</i> <	
	STA	LF ₁	LF ₂		Treatment ²	Recommended ³
Upper sieve (>19.00)	4.84 ^b	6.36 ^a	6.35 ^a	0.34	0.05	2.0–8.0
Middle sieve (19.00–8.00)	42.9 ^{ab}	44.1 ^a	41.3 ^b	0.65	0.05	30.0–50.0
Lower sieve (8.00–1.18)	35.7 ^{ef}	34.7 ^f	35.9 ^e	0.47	0.05	30.0–50.0
Bottom pan (<1.18)	16.6 ^a	14.8 ^b	16.4 ^a	0.44	0.02	<20.0

^{a,b}Least squares means within the same row with different superscripts differ ($P < 0.05$).

^{e,f}Least squares means within the same row with different superscripts differ ($P < 0.10$).

¹STA = Dekalb blend corn silage (Monsanto Company, St. Louis, MO); LF₁ = Masters Choice 527 corn silage; LF₂ = Masters Choice 5250 corn silage.

²Probability of *F*-test for treatment.

³Adapted from Heinrichs and Kononoff (2002).

Table 6. Intake of DMI, NDF, digestible NDF, starch, corn silage starch, and ruminal degradable corn silage starch intake by early-lactation dairy cows fed TMR differing in corn silage hybrids

Measurement	Treatment ¹			SEM	<i>P</i> < Treatment ²
	STA	LF ₁	LF ₂		
Lactating cows, no.	7	7	7	—	—
DMI, kg/d	22.9	23.5	22.4	0.78	0.46
NDF intake, kg/d	6.44 ^b	7.13 ^a	7.30 ^a	0.35	0.03
NDF intake, % of BW	0.99 ^b	1.10 ^a	1.12 ^a	0.04	0.04
Digestible NDF intake, ³ kg/d	3.17 ^b	3.66 ^a	4.00 ^a	0.06	0.01
Digestible NDF intake, ³ % of BW	0.49 ^b	0.57 ^a	0.61 ^a	0.02	0.01
Starch intake, kg/d	5.96 ^a	5.53 ^b	5.27 ^b	0.26	0.10
Starch intake, % of BW	0.92 ^a	0.86 ^b	0.81 ^b	0.03	0.07
Corn silage starch intake, kg/d	4.07 ^a	3.56 ^b	3.40 ^b	0.17	0.01
Corn silage starch intake, % of BW	0.63 ^a	0.55 ^b	0.52 ^b	0.02	0.01
Corn silage ruminal degradable starch intake, ³ kg/d	2.78 ^a	2.78 ^a	2.48 ^b	0.13	0.13
Corn silage ruminal degradable starch intake, ³ % of BW	0.43 ^a	0.43 ^a	0.38 ^b	0.01	0.04

^{a,b}Least squares means within the same row with different superscripts differ ($P < 0.05$).

¹STA = Dekalb blend corn silage (Monsanto Company, St. Louis, MO); LF₁ = Masters Choice 527 corn silage (Masters Choice, Anna, IL); LF₂ = Masters Choice 5250 corn silage.

²Probability of *F*-test for treatment.

³Nutrient concentration × in vitro digestibility × DMI expressed as kg/d or % of BW.

DMI compared with conventional corn silage hybrids. Calculations of NDF intake and digestible NDF (NDF × NDFd) intake as kg/d and % of BW demonstrated that cows fed LF₁ and LF₂ consumed more ($P < 0.05$) digestible fiber than cows fed STA. It is possible that gut fill could be limiting DMI for cows fed LF₁ and LF₂ compared with cows fed STA. In contrast, cows fed STA consumed more ($P < 0.05$) starch intake as kg/d and % of BW compared with cows fed LF₁ and LF₂. Thus, cows fed LF₁ and LF₂ consume more digestible fiber than cows fed STA, whereas cows fed STA consumed more starch. The 7-h starch digestibility was only conducted on the experimental corn silages and not the entire TMR; therefore, calculations are based only on the corn silage contribution to the ration (Table 1). This calculation would eliminate or ignore the corn starch contribution, which was similar across all experimental diets. The amount of corn silage starch was greater ($P < 0.05$) for cows fed STA compared with cows fed LF₁ and LF₂; however, the amount of rumen degradable starch coming from corn silage was similar ($P > 0.10$) for cows fed STA and LF₁, which was greater ($P < 0.05$) when compared with cows fed LF₂ when expressed as kg/d or % of BW. These data demonstrate that similar amounts of ruminal degradable starch can be achieved with a lower corn silage starch concentration that is more ruminally digestible. Mertens (2016) suggested a total NDF intake of 1.25% of BW can maximize forage intake, while meeting the energy requirements of the lactating dairy cow. Grant et al. (2018) reported that increasing undigestible NDF as a % of DM resulted in a linear decreased in DMI. In contrast, calculating undigestible NDF at 240

h as a percentage of BW resulted in concentrations of 0.38, 0.41, and 0.41% of BW, respectively, which would indicate that the amount of indigestible NDF may be limiting intake, but more work is needed in this area (Mertens, 2016). The goal for maximizing nutrient intake would be through combining increased ruminal starch digestion with increased ruminal NDF digestion.

Milk Production and Composition

Production of milk, 3.5% FCM, and ECM was similar ($P > 0.10$) among dairy cows fed the 3 treatments containing experimental corn silages (Table 7). Kuehn et al. (1999), Ballard et al. (2001), and Nennich et al. (2003) also reported similar milk yields when conventional and leafy corn silage hybrids were fed to lactating dairy cows. However, Thomas et al. (2001) and Clark et al. (2002) reported greater milk yields by cows fed diets containing leafy corn silage hybrids than cows fed conventional hybrids. Hassanat et al. (2017) reported higher milk yield, 4% FCM yield, and ECM yield when cows were fed BMR corn silage instead of conventional corn silage. A meta-analysis by Ferraretto and Shaver (2015) reported an increase of 1.0 kg/d of milk production for cows fed highly digestible fiber corn silage hybrids compared with conventional corn hybrids, but 3.5% FCM yields were similar. This increase in milk production was similar to the increase in milk production when feeding BMR corn silage, which indicates that both types of corn silage hybrids are enhancing milk production via increased fiber (NDF) digestibility. The concern with the literature to date is these corn silage hybrid lactation studies have not been conducted

Table 7. Yield of milk, 3.5% FCM and ECM, milk composition, MUN, feed efficiency (FE), BW, and BCS by early-lactation dairy cows fed TMR differing in corn silage hybrids

Measurement	Treatment ¹			SEM	<i>P</i> < Treatment ²
	STA	LF ₁	LF ₂		
Lactating cows, no.	7	7	7	—	—
Milk, kg/d	35.6	34.8	36.1	1.18	0.63
Fat, %	4.17	3.94	3.71	0.21	0.30
Fat yield, kg/d	1.47	1.36	1.34	0.57	0.14
Protein, %	3.12	3.09	3.03	0.08	0.61
Protein yield, kg/d	1.12	1.07	1.10	0.06	0.74
SCC, 10 ⁵ cells/mL	4.57	4.75	4.64	0.16	0.62
Lactose, %	4.93	4.92	4.92	0.04	0.95
SNF, %	8.96	8.92	8.85	0.07	0.31
MUN, mg/dL	13.6 ^b	15.0 ^a	15.0 ^a	0.54	0.02
3.5% FCM, ³ kg/d	38.7	36.5	37.6	1.41	0.16
ECM, ⁴ kg/d	38.2	36.1	38.1	1.42	0.16
BW change, kg/d	−0.10	−0.06	−0.08	0.04	0.48
Average BW, kg	646.7	647.7	647.8	7.95	0.98
BCS change/d	−0.05	−0.04	−0.05	0.04	0.71
FE, milk/DMI	1.60	1.52	1.68	0.08	0.22
3.5% FCM FE	1.79	1.61	1.67	0.07	0.19

^{a,b}Least squares means within the same row with different superscripts differ ($P < 0.05$).

¹STA = Dekalb blend corn silage (Monsanto Company, St. Louis, MO); LF₁ = Masters Choice 527 corn silage (Masters Choice, Anna, IL); LF₂ = Masters Choice 5250 corn silage.

²Probability of *F*-test for treatment.

³3.5% FCM = $(0.4324 \times \text{milk yield}) + (16.216 \times \text{fat yield})$.

⁴ECM = $(0.327 \times \text{milk yield}) + (12.95 \times \text{fat yield}) + (7.20 \times \text{protein yield})$.

on nutrient availability and digestibility basis, but only by hybrid comparisons. Casper and Mertens (2007), in their summary of more than 40 yr of energy metabolism studies, demonstrated that digestibility was the biggest factor limiting energy intake by the lactating dairy cow and the major factor in ration digestibility would be forage fiber digestibility.

Milk fat and milk protein percentages were similar ($P > 0.10$) among all treatments. In addition, milk fat and milk protein yields (kg/d) were similar ($P > 0.10$) among treatments. Nennich et al. (2003) reported similar percentages and yields of milk fat and protein when lactating dairy cows were fed conventional and leafy corn silage hybrids. In contrast, Thomas et al. (2001) reported a trend toward greater protein yield from cows fed a leafy corn silage hybrid diet. Clark et al. (2002) reported a 0.05 kg/d increase in milk fat production for cows fed a leafy corn silage hybrid ration compared with a ration containing conventional corn silage hybrids. Kuehn et al. (1999), Bal et al. (2000), Ballard et al. (2001), and Nennich et al. (2003) reported no improvement in FCM yield from feeding leafy corn silage hybrids over conventional corn silage hybrids, whereas Thomas et al. (2001) and Clark et al. (2002) reported an increase in FCM yield, while feeding leafy corn silage hybrids over conventional corn silage hybrids. Hassanat et al. (2017) reported lower milk fat % and MUN but higher milk fat yield, protein yield,

and lactose yield when BMR silage was fed compared with conventional corn silage.

Percentages of lactose and SNF, along with SCC, were similar ($P > 0.10$) for early-lactation dairy cows fed all treatments. Similar milk SCC were reported by Nennich et al. (2003) when conventional and leafy corn silage hybrids were fed to lactating dairy cows. Hassanat et al. (2017) reported similar lactose % and SCC, but higher lactose yield when BMR silage was fed compared with conventional corn silage. Ferraretto and Shaver (2015) reported similar lactose and protein concentrations and yields among many different types of corn silage hybrids. If corn silage hybrid was going to affect milk composition, the major effect would be on milk fat concentrations followed by milk protein in contrast to other milk components.

Milk urea nitrogen was lower ($P < 0.05$) for cows fed a ration containing STA corn silage compared with cows fed a ration containing LF₁ and LF₂ corn silage, which followed the higher starch and lower CP concentration of the STA corn silage. Since the STA diet has about 0.5% lower CP and more starch compared with LF₁ and LF₂ diets, we were expecting lower MUN in STA than LF₁ and LF₂ diets. Hassanat et al. (2017) reported lower MUN when fed BMR silage compared with conventional corn silage. However, Ferraretto and Shaver (2015) reported that greater NDF digestibility resulted in lower MUN due to more ammonia being

incorporated into microbial protein. In contrast, this study is confounded by both lower CP and greater NDF and starch digestibilities, which may make drawing specific conclusion(s) speculative.

BW and BCS

Body weight, BCS, and change in BW and BCS were similar ($P > 0.05$) among treatments (Table 7) during the 9-wk, early-lactation study. The early-lactation cows would be expected to be losing BW and BCS during this period of the lactation. Cows in this study were losing less BW than reported by Holt et al. (2013), but our milk production was slightly lower. Given the similar milk production, milk composition, BW, and BCS changes would indicate that all rations were similar in energy concentrations and digestibility. However, given the differences in nutrient concentrations and intake (Tables 3, 4, and 6), a greater portion of the digestible energy was being supplied by starch for cows fed STA rations compared with digestible fiber and fast starch digestion (greater 7-h starch digestion) for cows fed LF₁ and LF₂ rations.

Ruminal pH, Ammonia, and VFA

Ruminal pH was lower ($P < 0.05$) for cows fed STA compared with cows fed LF₁ and LF₂ corn silage rations (Table 8). The high starch concentration of the STA ration would be expected to lower ruminal pH compared with a higher fiber rations of cows fed LF₁ and LF₂. Lower ruminal pH was reported by Cherney et al.

(2004) when cows were fed BMR and conventional corn hybrid silage compared with leafy hybrid corn silage, which would be the result of greater ruminal digestion of fiber and starch. In their summary across several different corn silage hybrids, no differences in ruminal pH were observed (Ferraretto and Shaver, 2015).

Rumen NH₃ concentrations were similar ($P > 0.10$) among all experimental corn silage rations. Total VFA concentrations (mmol) were higher ($P < 0.05$) for cows fed the STA ration compared with cows fed the LF₁ ration, but similar ($P > 0.10$) and intermediate for cows fed the LF₂ ration. Acetate molar concentrations were greater ($P < 0.05$) for lactating cows fed LF₁ and LF₂ rations compared with cows fed the STA ration, as would be expected due to the greater NDF concentrations and greater NDF digestibility of LF₁ and LF₂ corn silage. In contrast, cows fed the STA ration demonstrated greater ($P < 0.05$) molar concentrations of propionate compared with cows fed the LF₁ and LF₂ rations. The higher starch and lower NDF concentrations in the STA corn silage would be expected to shift ruminal fermentation to higher propionate and lower acetate molar concentrations. The shifts in ruminal fermentation resulted in the acetate to propionate and acetate plus butyrate to propionate ratios being greater ($P < 0.05$) for cows fed LF₁ and LF₂ rations compared with cows fed the STA ration. The molar concentration of isovalerate was greater ($P < 0.05$) for cows fed the STA ration compared with the cows fed LF₂ diet, with cows fed the LF₁ ration being similar ($P > 0.10$) and intermediate. The remaining VFA of isobutyrate, butyrate, and valerate were similar ($P > 0.05$) among

Table 8. Ruminal pH, ammonia, and VFA concentrations from early-lactation dairy cows fed different corn silage hybrids

Measurement	Treatment ¹			SEM	$P <$
	STA	LF ₁	LF ₂		Treatment ²
Lactating cows, no.	7	7	7	—	—
pH	6.31 ^c	6.69 ^a	6.50 ^b	0.08	0.01
NH ₃ -N, mg/dL	8.60	9.30	10.3	0.96	0.30
Total VFA, mmol/L	91.8 ^a	72.3 ^b	86.5 ^{ab}	6.21	0.10
mmol/100 mmol of total VFA					
Acetate	59.5 ^b	63.8 ^a	62.4 ^a	0.95	0.02
Propionate	26.1 ^a	21.0 ^b	23.1 ^b	0.87	0.01
Isobutyrate	0.58	0.59	0.55	0.05	0.80
Butyrate	10.9	11.9	11.3	0.57	0.47
Isovalerate	1.35 ^a	1.09 ^{ab}	1.00 ^b	0.13	0.15
Valerate	1.63	1.67	1.64	0.09	0.95
Acetate:propionate	2.32 ^b	3.10 ^a	2.81 ^a	0.12	0.01
Acetate + butyrate:propionate	2.74 ^b	3.67 ^a	3.32 ^a	0.14	0.01

^{a-c}Least squares means within the same row with different superscripts differ ($P < 0.05$).

¹STA = TMR with Dekalb blend corn silage (Monsanto Company, St. Louis, MO); LF₁ = TMR with Masters Choice 527 corn silage (Masters Choice, Anna, IL); LF₂ = TMR with Masters Choice 5250 corn silage.

²Probability of F -test for treatment.

treatments. Holt et al. (2013) fed conventional corn silage or BMR corn silage with high-quality alfalfa hay to early-lactation dairy cows and reported similar ruminal pH, total VFA, acetate, propionate, butyrate, and acetate:propionate ratio among cows fed conventional or BMR corn silage. Hassanat et al. (2017) also fed conventional or BMR corn silage and reported similar ruminal pH, total VFA, acetate, propionate, and butyrate but lower ruminal NH_3 concentration while feeding BMR corn silage. However, Oba and Allen (2000), Taylor and Allen (2005), and Gorniak et al. (2014) reported reduced mean ruminal pH when feeding BMR corn silage compared with conventional corn silage, which would be related to enhanced BMR corn silage nutrient digestibility. Ferraretto and Shaver (2015) in their meta-analysis reported that several different corn silage hybrids resulted in similar concentrations of ruminal ammonia, total VFA, and individual VFA concentrations. If rumen health is being maintained (i.e., cud chewing, ruminal pH, saliva production, passage rates, and so on), then corn silage hybrid may have little effect on VFA concentrations, even though total microbial and VFA production is being increased (i.e., g/d).

CONCLUSIONS

Seed corn hybrid selection is an important management decision for corn silage production to economically feed lactating dairy cows. New corn hybrids are introduced every year that could vary greatly in nutrient digestibility, so it is essential to evaluate their lactational response using energy-demanding early-lactation dairy cows. This study demonstrated that CP of LF_1 corn silage was higher than LF_2 and STA corn silage, whereas the starch content was higher for STA corn silage. The digestible NDF per unit of DM was lower for STA compared with LF_1 and LF_2 (14.0, 15.5, and 17.9% DM, respectively) corn silages, which implies that the LF_1 and LF_2 hybrids are supplying more digestible fiber. The growing season can affect vomitoxin concentrations in corn silage, which may have influenced lactational performance of the LF_1 and LF_2 hybrids. However, the similar DMI, milk production, and composition among hybrids demonstrate that feeding a lower starch, but higher digestible fiber, corn silage ration can support milk production compared with a higher starch, lower digestible NDF ration. The future of enhancing lactational performance would be to enhance both fiber and starch concentrations and digestibility to increase nutrient supply to early-lactation dairy cows without lowering pH, while increasing acetate and propionate production and microbial synthesis.

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ORCID

David P. Casper <https://orcid.org/0000-0002-0666-8808>