Short communication: Risk of subacute ruminal acidosis affects the feed sorting behavior and milk production of early lactation cows

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ABSTRACT

The objective of this study was to determine if the risk of developing subacute ruminal acidosis, as potentially affected by dietary straw particle size, influenced the feed sorting, rumination behavior, and milk production of early lactation dairy cows. Upon calving, 41 multiparous Holstein cows were fed a total mixed ration with 9% wheat straw (dry matter basis) chopped (1) using a 2.54-cm screen (short; $n = 21$) or (2) using a 5.08-cm screen (long; $n = 20$). For the first 4 wk following calving, rumination behavior (recorded using data loggers attached to neck collars) and reticulorumen pH (recorded using wireless telemetry boluses) were monitored 24 h/d. Due to technical failures, analyses were conducted on 38 cows ($n = 19$ per treatment). Total mixed ration and Orts samples were collected every 3 d to determine feed sorting. Based on an acidosis index, created using area under the curve data (reticulorumen pH < 5.8) normalized for dry matter intake, cows were categorized as either low (LR) or high (HR) risk for developing subacute ruminal acidosis (SARA). Low risk cows had higher mean (6.3 vs. 6.1), minimum (6.0 vs. 5.7), and maximum (6.7 vs. 6.5) reticulorumen pH than HR cows. Low risk cows also had less severe area under the curve values (1.5 vs. 49.4 pH $\times$ min/d) and spent less time below a reticulorumen pH threshold of 5.8 (21.9 vs. 309.2 min/d). Although total milk yield was unaffected by SARA risk, LR cows produced more 4% fat-corrected milk (47.2 vs. 41.9 kg/d) and milk fat (2.1 vs. 1.8 kg/d) than HR cows. A SARA risk category $\times$ treatment interaction was detected for sorting all fractions of the diet; HR cows on the long treatment sorted against the longest particles in the diet, whereas LR cows on the same treatment did not sort this fraction, suggesting that SARA risk may be mitigated by a more balanced intake of physically effective

fiber. High risk cows on the short treatment consumed the longest dietary particles as predicted, and sorted in favor of the physically effective medium and short particles. A SARA risk category $\times$ treatment interaction was detected for rumination behavior; within the long treatment, HR cows tended to ruminate less than LR cows (432.3 vs. 493.2 min/d). Overall, these results suggest that LR cows consumed a more balanced diet, whereas HR cows sorted their feed more, particularly when fed the diet containing long straw particles, which may have led to reduced rumination activity and yield of milk fat and fat-corrected milk.

Key words: dairy cow, sorting, ruminal acidosis

Short Communication

Early lactation dairy cows are particularly susceptible to SARA because of the abrupt transition from a dry diet, composed of primarily forages and minimal grain, to a high-energy lactation diet containing a greater proportion of readily digestible concentrate components (Steele et al., 2016). Adequate forage consumption is necessary for early lactation cows; forages may increase rumination and saliva production and, thus, reduce risk of SARA, but will also limit intake if the inclusion rate is too high (Allen, 1996). Limiting intake is undesirable for early lactation dairy cows because they are already experiencing a lag in DMI compared with milk production and need to maximize intake to meet energy demands for lactation (Allen, 1996).

The risk of SARA is not only linked to the diet provided, but also the diet consumed by the cow. Sorting of a TMR by dairy cows can result in the ration actually consumed by cows being greater in fermentable carbohydrates than intended and lesser in effective fiber, thereby increasing the risk of depressed rumen pH (DeVries et al., 2008). It is noteworthy that lactating dairy cows experiencing low ruminal pH may change their sorting behavior, sorting in favor of the longest, most physically effective particles in the diet (Beauchemin and Yang, 2005). DeVries et al. (2008) demonstrated that risk of SARA may affect such sort-

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ing behavior, finding that early lactation cows (39 to 78 DIM) at higher risk for SARA sorted their feed to maximize intake of physically effective fiber after experiencing an acute bout of ruminal acidosis more so than mid lactation cows (52 to 232 DIM) at lower risk for SARA.

To date, no data are available on the association of SARA risk and sorting in cows in the immediate postpartum period. Thus, an objective of this research was to determine how risk of developing SARA affects the feed sorting behavior and milk production of early lactation cows. It is known that long forage particles are more easily discernible and, therefore, more often sorted against than smaller forage particles (Miller-Cushon and DeVries, 2017). Reducing particle size of forages for early lactation cows should, thus, reduce the imbalance of nutrients consumed by those cows at highest risk for SARA. Thus, another objective of this research was to determine if straw particle size in the diet of early lactation dairy cows is related to risk of SARA and, if so, how it influences the behavioral and production outcomes of these animals. It was predicted that cows experiencing chronically low reticulorumen pH would sort their feed to minimize the negative consequences of this condition and that this behavior would be more apparent in cows fed a diet that is more easily sorted (i.e., with longer straw particles). Additionally, it was predicted that cows fed a diet that is more easily sorted would be at greater risk of SARA as result of consuming an unbalanced diet. It was also predicted that cows experiencing chronically low reticulorumen pH would spend less time ruminating and have decreased milk production.

This research was part of a larger study aimed at identifying the effect of straw particle size on the behavior, health, and milk production of early lactation dairy cows. As such, more detailed descriptions of the methodology of the study are presented in Coon et al. (2018). The study took place at the University of Guelph Livestock Research and Innovation Centre Dairy Facility (Elora, Ontario, Canada), where 41 multiparous cows (parity = 2.8 ± 1.1 postcalving; mean $\pm$ SD) were housed and milked 2 $\times$ /d at 0500 and 1700 h in a milking parlor. The use of cows and experimental procedures complied with the guidelines of the Canadian Council on Animal Care (2009) and were approved by the University of Guelph Animal Care Committee (Animal Use Protocol #2518). Cows were enrolled in the study approximately 17 d before calving and housed in a close-up pen fitted with automated feed bins (In-sentec B.V., Marknesse, the Netherlands). Cows were each assigned to a bin and trained to eat only from that feeder, allowing for individualized intake data collection. Before calving (3.1 ± 3.2 d) and for a short

period of time after (5.2 ± 3.3 d), cows were individually housed in a maternity pen with individual access to food and water. After calving, cows were moved to a freestall pen, with a cow-to-bin ratio of 1:1, allowing for individualized intake data collection.

The treatments consisted of feeding cows 1 of 2 fresh cow diets, randomly assigned at calving, and fed for the following 4 wk. Treatment allocation was balanced for parity and milk production in the previous lactation ($10,334.4 \pm 1,955.7$ kg). Treatment diets only differed in 1 aspect, the length of the wheat straw component in that diet: (1) straw chopped with a 2.54-cm screen (short; $n = 21$) or (2) straw chopped with a 5.08-cm screen (long; $n = 20$). For both treatments, straw was chopped using a bale processor (Haybuster Model H-1150, Jamestown, ND) with a screen size of 2.54 or 5.08 cm to achieve the respective treatment particle lengths. Due to technical failures of 3 reticulorumen pH boluses, all analyses were conducted using a sample size of 38 cows (short: $n = 19$, long: $n = 19$). The long and short diets were identical in ingredient composition (on a DM basis): 34% corn silage, 9% wheat straw, 26% alfalfa haylage, 19% high moisture corn, and a 12% supplement. This diet was formulated to attempt, at minimum, to meet the nutrient requirements of early lactation dairy cows producing 36 kg/d (NRC, 2001). The diets averaged 49.0% DM, 15.7% CP, 22.6% ADF, 32.8% NDF, and 26.3% starch. Further details regarding the nutrient composition of the diets are found in Coon et al. (2018).

At the time of enrolment, cow BW was recorded (I-20W scale, Ohaus, Dundas, ON, Canada). Assessment of BW occurred once during the dry period at enrollment and every 14 d starting on d +4 postcalving for a total of 3 measurements including a final weighing on the last day of the trial period.

Rumination data loggers (HR-TAG-LD, SCR Engineers Ltd., Netanya, Israel), as validated by Schirmann et al. (2009), were attached to a nylon neck collar and fitted to each cow 2 wk before their expected calving date. Time spent ruminating each day was recorded in 2-h intervals, 24 h/d for the duration of the study.

Wireless telemetry boluses (eBolus, eCow Ltd., Devon, UK) were used to measure reticulorumen pH to assess rumen health (as validated by Falk et al., 2016). At time of enrollment, the boluses were administered orally using a balling gun. Data consisted of reticulorumen pH data points at 15-min intervals 24 h/d throughout the trial period that were then amalgamated into a continuous record for each individual cow.

Throughout the study, 2 fresh TMR samples were collected 3 $\times$ /wk: 1 sample was collected to determine DM for DMI calculation, and the other sample was collected to determine particle size distribution. Orts

samples were collected to determine particle size distribution every 3 d during the experimental period starting on d +4. All samples were immediately frozen at -20°C until further analysis.

Fresh and orts TMR samples collected for particle size analysis were processed using a 4-screen Penn State Particle Separator (**PSPS**; Maulfair et al., 2011; Jones and Heinrichs, 2013), which separates the sample into 4 fractions based on particle size: long (>19 mm), medium (<19 mm, >8 mm), short (<8 mm, >4 mm), and fine (<4 mm). Fresh TMR and separated samples were then oven-dried at 55°C for 48 h. Fresh TMR PSPS samples were ground to pass through a 1-mm screen (Model 4 Wiley Laboratory Mill, Thomas Scientific, Swedesboro, NJ). Ground samples, pooled by week, were then sent to Cumberland Valley Analytical Services Inc. (Maugansville, MD) for analysis of ADF (AOAC International, 2000: method 973.18) and NDF with heat-stable α -amylase and sodium sulfite (Van Soest et al., 1991). The particle distribution of the straw and experimental diets, along with the ADF and NDF content of the particle fractions of those diets, are found in Table 1.

Sorting of each PSPS fraction was calculated as per Leonardi and Armentano (2003) by dividing the actual amount of feed consumed of each fraction by the predicted amount of feed consumed of that fraction and expressing it as a percentage. If the sorting value equalled 100% then no sorting of the particle fraction

occurred; a value $<100\%$ indicated sorting against that particle size fraction, whereas a value $>100\%$ indicated sorting in favor of that particle fraction.

Milk yield was recorded at every milking in the milking parlor (using DelPro software, DeLaval, Peterborough, ON, Canada) for the 4 wk cows were observed on treatment. Milk samples were collected from each cow, at each milking, on 2 consecutive days each week starting at d +6. These samples were sent to a DHI testing laboratory (CanWest DHI, Guelph, ON, Canada) for component analysis (fat and crude protein) using a Fourier Transform Infrared full spectrum analyzer (Milkoscan FT+ and Milkoscan 6000; Foss, Hillerød, Denmark). One value per cow on each sampling day was obtained by calculating the average across milkings. Milk composition samples were used to determine the yield of 4% FCM (kg/d), calculated as $[0.4 \times \text{milk yield (kg/d)}] + [15.0 \times \text{fat yield (kg/d)}]$ (NRC, 2001).

Time below pH 5.8 was determined by summing time spent below pH 5.8 for each cow for each day. An absolute value for area below pH 5.8 was calculated by subtracting the pH value from 5.8 and multiplying it by the time spent at that pH value. These values were summed by day creating a single value for area under the curve (**AUC**; $\text{pH} \times \text{min}$) for each day for each cow. These values were normalized by dividing by DMI for each day for each cow (Penner et al., 2009). The normalized values were averaged by cow, creating a single

Table 1. Particle size distribution¹ (% DM) of the straw, the lactating cow diets (including straw), and fiber content of the particle fractions of those diets (mean $\pm$ SD)

Item	Long lactating diet ²	Short lactating diet ³
Straw (% of DM)		
Long	14.1 $\pm$ 6.9	1.4 $\pm$ 0.8
Medium	39.8 $\pm$ 4.7	25.0 $\pm$ 4.8
Short	17.4 $\pm$ 1.0	24.8 $\pm$ 1.7
Fine	28.6 $\pm$ 10.5	48.9 $\pm$ 3.4
TMR (% of DM), including straw		
Long	6.4 $\pm$ 4.2	4.2 $\pm$ 3.6
Medium	38.9 $\pm$ 5.7	39.4 $\pm$ 6.2
Short	19.3 $\pm$ 2.3	20.5 $\pm$ 3.4
Fine	35.4 $\pm$ 7.0	36.0 $\pm$ 7.0
ADF ⁴ (% of screen DM)		
Long	31.5 $\pm$ 1.0	28.9 $\pm$ 1.2
Medium	26.6 $\pm$ 0.9	25.8 $\pm$ 1.0
Short	18.6 $\pm$ 0.5	19.5 $\pm$ 1.0
Fine	13.9 $\pm$ 0.5	15.2 $\pm$ 1.2
NDF ⁴ (% of screen DM)		
Long	45.2 $\pm$ 1.2	40.7 $\pm$ 1.9
Medium	37.7 $\pm$ 1.6	36.6 $\pm$ 2.0
Short	28.2 $\pm$ 1.0	29.4 $\pm$ 1.8
Fine	21.2 $\pm$ 1.0	23.7 $\pm$ 1.7

¹Particle size determined by Penn State Particle Separator (Nasco, Fort Atkinson, WI), which has a 19-mm screen (long), 8-mm screen (medium), 4-mm screen (short), and a pan (<4 mm; fine).

²Straw in long lactating diet was chopped using a 5.08-cm screen.

³Straw in short lactating diet was chopped using a 2.54-cm screen.

⁴Values were obtained from chemical analysis of separated TMR samples.

value for each cow (expressed as $\text{pH} \times \text{min/kg}$ of DMI). An acidosis index was created from the values to classify cows based on risk of acidosis (Penner et al., 2009). Macmillan et al. (2017) defined risk of acidosis using an acidosis index threshold of 1.0 ($\text{pH} \times \text{min/kg}$) or greater. In that study pH was measured in the rumen fluid from the ventral rumen sac. In the present study pH boluses were located in the reticulorumen (Falk et al., 2016). The reticulum has a higher mean pH; it has been suggested that the SARA threshold for reticular fluid is 6.3 versus 5.8 for rumen fluid (Sato et al., 2012; Falk et al., 2016). As such, we chose to define our acidosis risk threshold to be an AUC/DMI ($\text{pH} \times \text{min/kg}$) value of 0.5 or greater. This classification was based on the distribution of this index for all cows; cows were classified as being low risk (**LR**) for developing SARA if AUC/DMI averaged less than 0.5 for the duration of the trial ($n = 25$; long: $n = 12$, short: $n = 13$). If the acidosis index averaged greater than or equal to 0.5 for the duration of the trial, a cow was classified as being high risk (**HR**) ($n = 13$; long: $n = 7$, short: $n = 6$).

All statistical analyses were conducted using SAS 9.4 software (SAS Institute Inc., Cary, NC). The experimental design used in this study was a completely randomized design. Significance was declared at $P \leq 0.05$ and tendencies were reported if $0.05 < P \leq 0.1$. If the P -value of an interaction term was ≤ 0.1 it was considered, otherwise interaction terms were disregarded. Before all analyses, data were tested for normality using the UNIVARIATE procedure of SAS; all assumptions of normality were met for all data. Residuals were compared with determine homogeneity of variance.

To investigate the effect of dietary treatment within SARA risk categories (high vs. low) on feed sorting, rumination, reticulorumen pH, DMI, DMI by BW, AUC, AUC/DMI, milk yield, FCM (4%), milk fat percentage, milk protein percentage, and milk fat and protein yield, data were summarized by week of lactation (1 to 4) and analyzed in a general linear mixed model using the MIXED procedure of SAS, treating week as a repeated measure. The model included the fixed effects of week, treatment, SARA risk, and the SARA risk $\times$ treatment and week $\times$ treatment interactions. The subject of the repeated statement was cow. Compound symmetry was selected as the covariance structure on the basis of best fit according to Schwarz's Bayesian information criterion. The PDIF procedure was used in the LSMEANS statement for analyzing differences between the SARA risk $\times$ treatment interactions when differences were detected.

To determine the occurrence of sorting within treatments and acidosis risk categories, the summarized data for each particle size was tested for a difference from

100 using t -tests (Leonardi and Armentano, 2003). Differences in sorting were analyzed using the previously described MIXED procedure model.

In the present study, cows categorized as LR had higher daily mean, maximum, and minimum reticulorumen pH than HR cows (Table 2). The LR cows experienced lower daily time spent below a reticulorumen pH of 5.8 and AUC than HR cows. These results are supported by Macmillan et al. (2017) and Nasrollahi et al. (2017), both of whom found that the pH variables measured were consistently lower in value, duration, and AUC for HR cows as compared with LR cows. It is noted that such recent studies (Gao and Oba, 2014; Macmillan et al., 2017; Nasrollahi et al., 2017), using similar methods of categorization for SARA risk, had higher acidosis index values for the HR cows than in the present study, indicating that SARA was more severe in those studies. In the present study, an effect of week ($P \leq 0.01$) was observed, with pH variables being slightly higher in wk 4 than in the previous 3 wk (data not shown), but no week $\times$ treatment interactions were detected. An overall increase in reticulorumen pH in wk 4 is expected given the greatest risk for SARA is immediately after calving (Penner et al., 2007). Risk of developing SARA had no effect on DMI or DMI as a percentage of BW (Table 2), which is consistent with the findings of Gao and Oba (2016) who found no difference in DMI between higher and lower risk mid-lactation cows fed a high-grain diet (forage = 30% of DM; Gao and Oba, 2016).

A SARA risk $\times$ treatment interaction was observed for sorting of all particle fractions ($P \leq 0.05$), which suggests that the sorting behavior of the cows varied depending on SARA risk category within treatment. No week $\times$ treatment interaction ($P \geq 0.45$) was detected for sorting behavior, nor an effect of week on sorting behavior ($P \geq 0.38$), suggesting that, like the pH variables measured, sorting remained consistent within treatment throughout the trial. High risk cows on the long treatment sorted against the long particles ($93.7 \pm 2.0\%$; $P = 0.004$), whereas HR cows on the short treatment did not sort this fraction of the diet ($105.5 \pm 3.4\%$; $P = 0.12$; Figure 1a). The straw in the long diet may have been long enough (cut with a 5.08-cm screen) that it was easily sorted against (Miller-Cushon and DeVries, 2017). Sorting against the long particles by cows on the long treatment may have resulted in a greater linear decrease in reticulorumen pH and a greater fluctuation in time spent below a reticulorumen pH of 5.8, as discussed by Coon et al. (2018). As discussed, cows on the short treatment, regardless of SARA risk, did not sort the long particles (Figure 1a), possibly because the straw particle size was small

Table 2. Effect of SARA risk on the reticulorumen pH, DMI, and milk production and composition¹ for lactating dairy cows in the first 28 d of lactation (mean ± SE)

Item	SARA risk ^{2,3}					
	Low risk			High risk		
	Short	Long	Short	Long	Status	Treatment
Mean reticulorumen pH	6.3 ± 0.04	6.4 ± 0.04	6.1 ± 0.06	6.0 ± 0.06	<0.001	0.64
Maximum reticulorumen pH	6.7 ± 0.04	6.8 ± 0.05	6.5 ± 0.07	6.4 ± 0.06	<0.001	0.59
Minimum reticulorumen pH	5.9 ± 0.04	6.0 ± 0.04	5.7 ± 0.06	5.7 ± 0.06	<0.001	0.52
Mean time below reticulorumen pH 5.8 (min/d)	20.0 ± 43.9	23.8 ± 45.7	275.8 ± 66.3	342.7 ± 60.0	<0.001	0.52
Area pH <5.8 (pH × min/d)	1.4 ± 9.0	1.5 ± 9.4	47.2 ± 13.6	51.6 ± 12.3	<0.001	0.84
Acidosis index (pH × min/kg of DMI)	0.08 ± 0.5	0.08 ± 0.5	3.4 ± 0.8	2.6 ± 0.7	<0.001	0.55
DMI (kg/d)	20.0 ± 0.7	18.9 ± 0.7	17.8 ± 1.0	19.0 ± 1.0	0.22	0.93
DMI as a percentage of BW (%)	2.6 ± 0.1	2.6 ± 0.1	2.5 ± 0.2	2.5 ± 0.1	0.32	0.84
Rumination (min/d)	461.3 ± 18.8	493.2 ± 19.6	478.50 ± 27.7	432.3 ± 25.7	0.35	0.76
Milk production (kg/d)						
Milk	39.2 ± 1.5	37.3 ± 1.5	36.0 ± 2.2	35.4 ± 2.0	0.18	0.50
4% FCM	47.6 ± 2.1	46.7 ± 2.2	43.0 ± 3.1	40.9 ± 2.8	0.05	0.56
Milk composition (%)						
Fat	5.1 ± 0.2	5.4 ± 0.2	5.3 ± 0.3	4.7 ± 0.2	0.26	0.47
Protein	3.3 ± 0.05	3.2 ± 0.05	3.2 ± 0.07	3.3 ± 0.06	0.92	0.46
Milk component yield (kg/d)						
Fat	2.1 ± 0.1	2.1 ± 0.1	1.9 ± 0.2	1.7 ± 0.1	0.04	0.60
Protein	1.3 ± 0.05	1.2 ± 0.05	1.2 ± 0.07	1.2 ± 0.07	0.12	0.62

¹Data were collected over 28 d (pH, milk yield, and DMI) or 2 d/wk (4% FCM and milk composition and component yield).

²Risk of developing SARA was calculated using an acidosis index of 0.5, calculated by determining area below pH 5.8 and dividing by DMI, averaged across the trial period. Low risk cows had an acidosis index less than 0.5, and high risk cows had an acidosis index greater than 0.5.

³Low risk, n = 25; high risk, n = 13.

enough (Table 1) to be more homogeneous with the ration and less easily distinguished.

A SARA risk $\times$ treatment interaction was detected for daily rumination time (Table 2); LR cows on the long treatment tended ($P = 0.07$) to have higher daily rumination time than HR cows on the long treatment. This may be explained by the sorting direction of cows on the long treatment. Both HR and LR cows on the long treatment sorted against long particles (Figure 1a). Cows sorted the medium particles differently by SARA risk within the long treatment ($P = 0.03$); HR sorted against the medium particles ($97.8 \pm 1.4\%$), whereas LR cows did not sort this fraction ($101.7 \pm 1.1\%$; Figure 1b). In sorting against both the long and medium particles, HR cows on the long treatment reduced their intake of physically effective fiber and subsequently would have ruminated less (Zebeli et al., 2012; Shaani et al., 2017). A SARA risk $\times$ treatment interaction was detected for milk fat percentage. Within cows on the long treatment, LR cows had higher milk fat percent-

age than HR cows, whereas no difference was observed between LR and HR cows on the short treatment. It is plausible that reduced intake of physically effective fiber, as result of sorting, led to a reduction in rumination by HR cows on the long treatment, which may have then altered the pH environment and VFA profile, as described by Nasrollahi et al. (2017). Nasrollahi et al. (2017) postulated that rumen fermentation changes in SARA-intolerant cattle result in the production of *trans*-10,*cis*-12 CLA, whose presence is related to milk fat depression (Grinari et al., 1998; Enjalbert et al., 2008; Alzahal et al., 2010).

Although no differences were detectable between groups for daily milk yield, LR cows produced more 4% FCM per day than HR cows (Table 2). Lower risk cows yielded more milk fat than higher risk cows (Table 2). These findings are consistent with the milk fat depression seen in cows experiencing low rumen pH (Grinari et al., 1998; Enjalbert et al., 2008; Alzahal et al., 2010). Consequently, milk and milk fat production usually

Figure 1. Sorting (%; mean $\pm$ SE) of (A) long (>19 mm), (B) medium (<19 mm, >8 mm), (C) short (<8 mm, >4 mm), and (D) fine particles (<4 mm) for cows fed a TMR with 9% wheat straw (DM basis) chopped: (1) using a 2.54-cm screen (short; $n = 19$) or (2) using a 5.08-cm screen (long; $n = 19$). Cows were also categorized by reticulorumen pH status: (1) low reticulorumen pH (high risk) for cows with an acidosis index {area under the curve for pH <5.8 [(pH $\times$ min/d)/DMI]} greater than 0.5 ($n = 13$; long: $n = 7$; short: $n = 6$) and (2) normal reticulorumen pH (low risk) for cows with an acidosis index less than 0.5 ($n = 25$; long: $n = 12$; short: $n = 13$). *Indicates a sorting value different from 100% ($P \leq 0.05$). †Indicates a tendency for a sorting value to be different from 100% ($0.05 < P \leq 0.1$).

decrease in cows suffering from SARA (Krause and Oetzel, 2006). Thus, greater 4% FCM yield and milk fat yield for the LR cows are likely a product of the numerically higher milk yield and milk fat percentage of these cows.

Higher risk cows on the long treatment did not sort the medium particles ($97.8 \pm 1.4\%$, $P = 0.11$), whereas HR cows on the short treatment tended to sort in favor of these particles ($102.7 \pm 1.5\%$, $P = 0.09$; Figure 1b). Only HR cows on the short treatment sorted the short and fine particles, sorting in favor of the short particles ($102.7 \pm 1.5\%$, $P < 0.001$; Figure 1c) and against the fine particles (93.4 ± 2.2 , $P = 0.005$; Figure 1d). Although not significantly different from 100%, HR cows on the short treatment demonstrated a positive numerical difference from 100% for sorting of the long particles, suggesting that these cows may have been sorting in favor of these particles, in addition to the medium and short particles, to ameliorate the effects of low reticulorumen pH. All of these particles (long, medium, and short) are physically effective (>4 mm), requiring further mastication and, thus, also stimulating further rumination (Maulfair et al., 2011). When experiencing an acute bout of ruminal acidosis, cows have been shown to sort in favor of the physically effective portion of the diet to alleviate the symptoms of low rumen pH, likely as a result of postingestive feedback (DeVries et al., 2008). Beef cattle have similarly been shown to sort in favor of the longest dietary particles when induced with an acute bout of ruminal acidosis (DeVries et al., 2014a), with those animals experiencing the greatest degree of acidosis demonstrating the greatest selection for long, fibrous particles (DeVries et al., 2014b). To further support the theory that dairy cows alter their preferences when experiencing SARA, Maulfair et al. (2013) found that dairy cows experiencing an acidosis challenge selected in favor of a diet that was more physically effective and had lower starch fermentability. Thus, it is possible that HR cows on the short treatment sorted in favor of the medium and short fractions and against the fine particles to ameliorate the negative effects of low reticulorumen pH. These results are consistent with DeVries et al. (2008), who found that cows with a high risk of SARA sorted in favor of the medium particles and against fine particles. In that study, high risk cows sorted against short particles, whereas the HR cows in the present study favored them. Again, this may be explained by a motivation to mitigate SARA. DeVries et al. (2008) categorized short particles as those retained between the 1.18-mm and 8-mm particle separator screens; meanwhile, in the current study short particles were defined as those retained between the 4-mm and 8-mm

screens. The short particles, as defined in the present study, may have been, on average, longer and more physically effective than those described by DeVries et al. (2008), which would provide an explanation for why HR cows sorted in favor of them to minimize the negative symptoms of SARA.

Aside from the long particles, which LR cows on the long treatment sorted against, LR cows on both treatments did not sort any of the remaining 3 fractions ($P \geq 0.12$; Figure 1). Minimal sorting would have resulted in a more balanced intake of nutrients, which may have contributed to a reduced risk of SARA in those cows (DeVries et al., 2008).

In summary, cows categorized as HR on the long treatment sorted against the longest particles in the diet, which may have contributed to their reduced time spent ruminating and, subsequently, their reduced milk fat percentage. Low reticulorumen pH may have resulted in decreased lipogenesis, leading to lower 4% FCM and milk fat yield for HR cows compared with LR cows. In contrast, HR cows on the short treatment may have been attempting to ameliorate the effects of low reticulorumen pH by maximizing intake of physically effective fiber by favoring the medium and short particles, and avoiding the fine particles. Aside from sorting the longest particles on the long treatment, LR cows did not sort their ration, regardless of treatment, and thus would have maintained a more balanced intake of nutrients.

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