Activity and rumination of Holstein and crossbred cows in an organic grazing and low-input conventional dairy herd

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ABSTRACT: Holstein and crossbred dairy cows from an organic grazing and low-input conventional herd were evaluated for activity and rumination across 4 yr (January 2014 to December 2017). Data were from two herds, an organic grazing (ORG) and a low-input conventional (CONV) that were managed similarly at the University of Minnesota West Central Research and Outreach Center, Morris, MN. Breed groups and total cows across the 4-yr study in the analysis for both herds were Holstein (HO, n = 114), 1964 HO genetic line (H64, n = 83); crossbreds sired by Montbéliarde, Viking Red, and HO (MVH, n = 248), and Normande, Jersey, and Viking Red (NJV, n = 167). During the summer grazing season (May to October) ORG cows were on pasture and supplemented daily with 2.72 kg of corn per cow, and CONV cows were fed a total mixed ration (TMR) in an outdoor confinement dry-lot. During the winter season (November to April) ORG and CONV cows were fed a TMR consisting of corn silage, alfalfa haylage, corn, soybean meal, and minerals in an outwintering lot and a compost barn. Activity (reported in activity units by daily and bihourly periods) and rumination, (min/d and min/2 h) from SCR DataFlow II software, were monitored electronically using HR-LD Tags (SCR Engineers Ltd, Netanya, Israel) for the 4-yr period. Daily activity was greater for 2016 and 2017 ($P < 0.05$) than for 2014 and 2015 for the ORG and CONV herds. Daily rumination varied by year, and 2015 and 2016 were lower ($P < 0.05$) than 2014 and 2017 in both herds. The HO and crossbred cows were not different ($P > 0.05$) for activity in both the ORG and CONV herds. The H64 cows had lower ($P < 0.05$) rumination than the other breed groups in the ORG and CONV herds. For ORG primiparous cows, the H64 cows had lower rumination than MVH cows, and the ORG multiparous H64 cows had lower ($P < 0.05$) rumination than HO and MVH breed groups. For CONV primiparous cows, the HO cows had greater ($P < 0.05$) rumination the other breed groups, and the CONV multiparous HO, MVH, and NJV cows had greater ($P < 0.05$) rumination than the H64 cows. Results from this study suggest that activity and rumination are different between breeds in the experimental low-input dairy herds.

Key words: activity, crossbreeding, grazing, organic, rumination

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INTRODUCTION

Activity and rumination monitoring systems (ARS) may be used to facilitate management and provide information for dairy producers with

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grazing and nonconventional dairy herds. In a confinement herd, Schirmann et al. (2009) found the HR Tag (SCR Dairy, Netanya, Israel) accurately recorded rumination accurately compared to visual observation. Elischer et al. (2013) also validated the HR Tag (SCR Dairy) in an automated milking grazing Holstein (HO) herd and reported the HR tag (SCR Dairy) to record activity and rumination with lower accuracy. However, in the validation study with an automated milking grazing system, the authors did state that activity and rumination could provide adequate information to dairy producers about cow movements and individual rumination time (Elischer et al., 2013).

There is little research information on other ARS besides the HR tag (SCR Dairy) in grazing dairy herds in the United States, especially within organic dairy production systems (ORG). Many grazing farmers prefer mixed breed herds (Sato et al., 2005) and some prefer crossbred herds. Crossbreds tend to stay in the herd longer and have more desirable fertility rates (Buckley et al., 2014), which are favorable to an ORG herd because the use of fertility hormones is prohibited (USDA-NOP, 2017). Yet, few studies have compared breed groups for activity and rumination in grazing herds in the United States. In a confinement herd, it was reported that HO was not different from Jersey (JE) or crossbreds of HO and JE for activity in first lactation; however, HO cows had lower activity than crossbred cows in later lactations (Stone et al., 2017).

In another study, rumination of Swedish Red cows was compared with HO cows in a free-stall herd. Some variation in rumination was based on diet; however, variation in rumination between cows was also high (Byskov et al., 2015). In a New Zealand grazing herd, no relationships were found among breed, genetic merit, and daily rumination of Friesian cows compared to Friesian × JE cows (Gregorini et al., 2013). To our knowledge, daily activity and rumination of HO and crossbred cows composed of JE, Montbéliarde, Normande, and Viking Red has not yet been reported. The objective of this study was to evaluate the daily activity and rumination of ORG grazing and low-input conventional HO and crossbred dairy cows. Activity and rumination comparisons of dairy breeds and crossbreds have seldom been studied. Large data files collected in the field and within designed experiments involving dairy breeds and crossbred dairy cattle are not systematically evaluated at this time. Therefore, data from institutional research herds, although limited in scope, are valuable to assess activity and rumination of HOs and crossbred dairy cattle.

MATERIALS AND METHODS

Herd Management

This study was conducted from January of 2014 to December of 2017 at the University of Minnesota West Central Research and Outreach Center, Morris, MN. Animal care and management were approved by the University of Minnesota Institutional Animal Care and Use Committee (#1508-32966A). The experimental research herd is a 300-cow dairy that is split into an ORG and low-input conventional herd (CONV). Cows were milked twice per day in a swing-9 parabone milking parlor. The ORG herd was milked at 0600 hours in the morning, followed by the CONV herd at 0800 hours and the ORG herd was milked at 1700 hours in the evening followed by the CONV herd at 1900 hours.

During the grazing season (May to October), the ORG herd was allowed on pasture for 20 h per day in accordance with the USDA National Organic Program pasture rule (USDA-NOP, 2017), which requires ORG dairy cows to graze for at least 120 d and receive 30% of their daily dry matter intake (DMI) from pasture. The pastures were composed of a mixture of diverse grasses and legumes that included smooth bromegrass (*Bromus inermis* Leyss.), orchard grass (*Dactylis glomerata*), meadow fescue (*Festuca pratensis*), alfalfa (*Medicago sativa*) red clover (*Trifolium pratense*), white clover (*Trifolium repens*), and kura clover (*Trifolium ambiguum* Bieb.) Cows were stocked at a rate of three cows per ha and were rotated to new paddocks every 2 d based on forage availability measured using Electronic Filip's folding plate pasture meter (Jenquip, Feilding, New Zealand). In addition to pasture, each ORG cow was supplemented with 2.72 kg of organic ground corn daily and had free-choice access to minerals from a feeder placed at ground level in each paddock. Cows had ad libitum access to water from a water trough also placed at ground level in each paddock. During the winter months (November to April), ORG cows were moved to an outwintering lot and fed a TMR consisting of primarily corn silage, alfalfa haylage, ground corn, soybean meal, and minerals. For the CONV herd, cows were fed a TMR in an outdoor confinement dry-lot during the summer and a compost-bedded pack barn during the winter. A nutritionist formulated diets for both herds and diets met the nutrient requirements for lactating cows (NRC, 2001). Table 1 includes the ingredient and nutrient composition of diets, averaged across the study time by herd and months. The ORG herd was on pasture during the

Table 1. Average diet[1] and nutrient composition of pasture and TMR, across the 4-yr study for the organic dairy herd and low-input conventional dairy herd

	Organic herd		Conventional herd	
Item	May to October	November to April	May to October	November to April
Ingredient, % of DM				
Corn silage		38.8	38.8	35.2
Alfalfa haylage		39.4	31.3	17.6
Ground corn	2.7	9.4	12.8	12.2
Dry grass hay		9.8	9.1	9.0
Vitamin and Mineral mix[2]	0.5	1.4	1.5	1.4
Soybean meal		1.2	3.9	3.8
Wet beet pulp				18.3
Distillers grains			2.9	2.7
Nutrient composition				
Dry matter, %	23.3	48.8	51.6	49.6
Crude protein, % of DM	23.0	14.6	15.0	15.0
Acid detergent fiber, % of DM	32.2	29.2	22.9	22.4
Neutral detergent fiber, % of DM	49.6	39.0	34.9	31.8
Non-fiber carbohydrates (%)	17.3	31.1	42.1	46.1

[1]Feed sample components were collected by a nutrition consultant on a monthly basis and pasture samples were collected on a weekly basis.

[2]Vitamin and mineral mix included calcium (13.0%), phosphorus (5.0%), salt (26.0%), magnesium (4.7%), potassium (0.6%), sulfur (1.2%), selenium (16 ppm), vitamin A (94,347 IU/kg), vitamin D_3 (23,587 IU/kg), vitamin E (376 IU/kg; Vita Plus Corporation, Madison, WI).

summer months and consumed little grain, with 85% of daily DMI provided from pasture. Pasture forage quality varied across the years of the study and the mean forage quality of the pasture was 18.0% for CP, 50.1% for NDF, and 27.2% for ADF (Ruh et al., 2018). Across the year, the ration for the CONV herd changed slightly, with the addition of wet beet pulp during the winter months.

The ORG and CONV herds calved seasonally and were bred to maintain a seasonal production system. Calving seasons were spring (March to May) or autumn (September to November) and breeding seasons were summer (June to August) or winter (December to February). Cows in both herds were culled on strict management decisions, based on fertility, somatic cell score, and production level. If cows did not become pregnant within two breeding seasons (June to August, summer or December to February, winter; 6 mo total), they were culled for poor fertility.

Mean, high, and low temperature, and total precipitation for summer and winter months during the 4-yr study were collected from the University of Minnesota West Central Research and Outreach Center, Morris, MN weather station. The average daily temperature for the summer months ranged from 15.9 °C in 2014 to 16.8 °C in 2016, and the average daily temperature for the winter months ranged from −7.3 °C in 2014 to −2.1 °C in 2016. Precipitation during the summer months ranged from 85.4 mm/mo in 2014 to 108.7 mm/mo in 2017. Precipitation during the winter months ranged from 21.9 mm/mo in 2017 to 36.9 mm/mo in 2014. The recorded temperatures and snowfall were similar to the 30-yr average in western Minnesota.

Breed Groups

Four breed groups of cows were evaluated for activity and rumination: contemporary HO, HO maintained at 1964 breed average level (H64), crossbred cows of HO, Montbéliarde, and Viking Red (MVH), and crossbred cows of Normande, JE, and Viking Red (NJV). The H64 cows originated from a design initiated at The University of Minnesota for comparison of the H64 and HO cows selected for production across time. Cows in the H64 line were bred to maintain a constant body size, and when mated, were not allowed to surpass an inbreeding coefficient of 6.25%. Hansen (2000) reported the H64 cows were smaller, had less body depth, had less dairy character and more body condition compared to contemporary HO cows selected for production. The H64 results in the current study would be applicable to researchers interested in genetic variation for these two HO breed groups for activity levels and rumination for genetic, nutritional and nutritional physiological research studies. However, because the genetics of the H64 cows are rarely observed in today's contemporary HO, the H64 results would have limited applicability to dairy producers.

All crossbred cows in the study, were three-breed rotational crossbreds of their respective

crossbreeding design. The University of Minnesota West Central Research and Outreach Center research herd began crossbreeding during 2000 when pure HO heifers and cows were randomly assigned to either a HO line or crossbred line. The heifers and cows in the HO line were mated to HO artificial insemination (AI) bulls, and the HO heifers and cows in the crossbred line were mated to JE AI bulls. All JE × HO crossbred heifers and cows were mated to Montbéliarde bulls to initiate a three-breed rotational system. Subsequently in 2002, some HO multiparous cows were also mated to Montbéliarde AI bulls to provide comparison of HO and Montbéliarde × HO crossbreds. The multiparous HO cows from 2002 to 2004 were randomly mated to either Montbéliarde AI bulls or HO AI bulls. Initially, the Montbéliarde × HO were mated to JE AI bulls; however, in 2009, the Montbéliarde × HO cows were mated to Viking Red AI bulls, based on shortcomings of the JE breed in a confinement rotational crossbreeding system (Heins et al., 2011). From 2009 until the present, all three-breed crossbreds were mated to HO AI bulls to create a three-breed crossbreeding rotation of HO, Montbéliarde and Viking Red.

Beginning in 2003, a new and separate three-breed crossbreeding rotation was developed for the ORG and CONV herds. Therefore, a herd of JE × HO crossbred heifers were purchased to initiate the new crossbreeding rotation that would improve longevity, fertility, and health traits for grazing dairy cows. The initial heifers to start the rotation contained 50% HO genes. The JE × HO crossbred heifers were bred to Norwegian Red and Viking Red AI bulls. The resulting offspring were bred to Normande AI bulls, and the Normande-sired crossbred heifers and cows were mated to JE AI bulls to create a three-breed crossbreeding rotation of Viking Red, Normande and JE. The goal of this crossbreeding rotation was to remove HO from the rotation.

Three AI bulls were selected annually based on high ranking with the US Net Merit index (HO and JE; VanRaden et al., 2018), with the French total merit index (Montbéliarde, Montbéliarde Association, 2018; and Normande, Organisme de Sélection en Race Normande, 2018) and with the Nordic total merit index (Viking Red; Nordisk Avlsvaerdi Vurdering, 2018). Inbreeding coefficients were not allowed to surpass 6.25% for matings of HO heifers and cows with HO sires. The HO cows were sired by high ranking net merit bulls.

Data

At calving, all cows were equipped with an HR-LD tag activity and rumination collar (SCR Engineers Ltd, Netanya, Israel) around the neck (Schirmann et al., 2009). Activity (reported in daily activity units) were measured by head and neck movements of a cow by a triaxial accelerometer and the data were classified into an index that considers the intensity and direction of the head and neck movements (Van Hertem et al., 2013). Rumination (reported in minute per day) was monitored by a microphone and microprocessor contained within the collar tag (Elischer et al., 2013; Sjostrom et al., 2016). The ARS transferred data to a long distance antenna placed atop the milking parlor. Each time cows returned to the milking parlor or if they were on pasture near the milking parlor, data would be collected as often as every 20 min. Raw data were sent to the computer in the farm office and processed through the SCR DataFlow II software (Data Flow Software; SCR Engineers Ltd).

The initial dataset had 4,043,915 daily activity and rumination observations across the 4-yr study period. The UNIVARIATE procedure of SAS 9.4 (SAS Institute Inc., Cary, NC) was used to establish normality of daily activity and rumination data before statistical analysis. The first and 99th percentile values of the dataset were removed. Potential reasons for missing and abnormal data include data not being properly read from the collars to the barn antenna, ARS collars malfunctioning due to wear and tear, or the ARS collar was lost from a cow. After data edits, there were 3,351,775 observations. Lactations greater than five were excluded from the analysis. The lactations greater than five were excluded because the average number of lactations in a cow's lifetime is 2.8 (VanRaden et al., 2018), because older cows are more prone to reproductive and health challenges, and a majority of cows in US dairy herds are in the first three lactations. Fifty-nine cows were removed because of lactations greater than five. After all edits, there were 3,252,216 observations for statistical analysis.

Cow data (herd, lactation number, and calving date) were retrieved from PCDART software (Dairy Records Management Systems, Raleigh, NC) on the farm. Overall, 612 HO and crossbred cows were used for analysis (Table 2). First lactation observations (n = 509) were considered a primiparous group and lactation numbers 2 to 5 (n = 820) were combined into a multiparous group. The study included data from 114 HO, 83 H64, 248 MVH crossbreds, and 167 NJV crossbreds across

Table 2. Number of cows and lactation observations[1] by specific breed groups for the organic and low-input conventional dairy herds at the University of Minnesota West Central Research and Outreach Center, Morris, MN

		Primiparous			Multiparous		
	Total number of cows	Organic	Conventional	Total	Organic	Conventional	Total
Breed							
Holstein	114	18	70	88	18	143	161
1964 Holstein	83	37	23	60	60	50	110
MVH[2]	248	70	148	218	82	257	339
Montbéliarde-sired	86	33	51	84	24	51	75
Viking Red-sired	80	17	52	69	21	94	115
Holstein-sired	82	20	45	65	37	112	149
NJV[2]	167	118	25	143	171	39	210
Normande-sired	39	30	7	37	25	13	38
Jersey-sired	58	36	7	43	78	7	85
Viking Red-sired	70	52	11	63	68	19	87
Total	612	243	266	509	331	489	820

[1]Because the study spanned across 4 yr, cows (n = 390) had multiple lactations included in the data.

[2]MVH = crossbreds of Montbéliarde, Viking Red, and Holstein; NJV = crossbreds of Normande, Jersey, and Viking Red.

both herds. Within the ORG herd, there were data from 18 HO, 50 H64, 76 MVH, and 140 NJV crossbred cows, and within the CONV herd, there were data from 96 HO, 33 H64, 172 MVH, and 27 NJV crossbred cows.

Across the years, the ORG herd had an unadjusted average 305-d milk yield of 5,323 kg per cow and the CONV herd had an average 305-d milk yield of 7,012 kg. Within respective breed groups, the unadjusted average 305-d milk yield was 7,492 kg for the HO cows, 4,910 kg for the H64 cows, 6,701 kg for the MVH cows, and 5,426 kg for the NJV cows.

The unadjusted average post-partum BW across the study period were recorded biweekly using a digital scale (Tru-Test ID5000, Auckland, New Zealand). The average BW was 517 kg for the ORG herd and 570 kg for the CONV herd. The BW for breed groups were 592 kg for HO cows, 517 kg for H64 cows, 567 kg for MVH cows, and 499 kg for NJV cows.

Statistical Analysis

Data from each herd were analyzed separately; however the statistical model was the same for each herd. For statistical analysis of daily activity and rumination, independent variables were year (2014 to 2017), month (January to December), breed group (HO, H64, MVH, NJV), parity group (primiparous and multiparous), and the interactions of year and breed group, breed group and parity group, and parity group and year. Cow nested within breed group was a random effect. The autoregressive order 1 covariance structure was used because it resulted in the lowest Akaike information criterion (AIC) for repeated measures (Littell et al., 1998). Although careful consideration was carried out to remove interactions based on $P > 0.05$, the interactions included in the model helped to reduce the AIC value. For all measurements, the MIXED procedure (SAS Institute, 2014) was used to obtain solutions and conduct the ANOVA. All treatment results were reported as least squares means with significance declared at $P < 0.05$.

RESULTS AND DISCUSSION

The F-values and P-values from tests of significance from the statistical model for daily activity and rumination are in Table 3. For the ORG herd, the overall daily activity was greater ($P < 0.05$) for the multiparous cows (640) compared to the primiparous cows (575). For the CONV herd, the overall daily activity was greater ($P < 0.05$) for the multiparous cows (640) compared to the primiparous cows (573). Furthermore, multiparous cows had greater ($P < 0.05$) daily rumination for both the ORG (517 vs. 513 min/d) and CONV herd (512 vs. 494 min/d) compared to primiparous cows.

The least square means and standard error of means for daily activity and rumination for the ORG and CONV herd for each specific year are in Table 4. Daily activity in both the ORG and CONV herd varied by year; however, daily activity was not different ($P > 0.05$) between 2016 and 2017 for both herds. Daily rumination varied by year, although

Table 3. F-values and *P*-values from tests of significance for daily activity and rumination[1]

	Organic herd						Conventional herd					
	Daily activity			Daily rumination			Daily activity			Daily rumination		
Independent variables[2]	Num df	F-value	*P*-value	Num df	F-value	*P*-value	Num df	F-value	*P*-value	Num df	F-value	*P*-value
Breed group	3	0.68	0.56	3	3.8	0.01	3	0.65	0.58	3	3.7	0.01
Month	11	4775.1	0.001	11	1108.8	0.001	11	5468.5	0.001	11	162.0	0.001
Year	3	172.5	0.001	3	8.0	0.001	3	567.2	0.001	3	202.0	0.001
Parity group	1	482.5	0.001	1	5.8	0.02	1	664.5	0.001	1	288.3	0.001
Breed group by year	9	80.8	0.001	9	21.8	0.001	9	57.0	0.001	9	12.0	0.001
Breed group by parity group	3	467.5	0.001	3	16.3	0.001	3	177.9	0.001	3	7.4	0.001
Parity group by year	3	113.5	0.001	3	25.8	0.001	3	192.1	0.001	3	61.3	0.001

[1]Activity and rumination were recorded by HR-LD Tag (SCR Engineers Ltd) with a 3-axis accelerometer and a microphone.

[2]Herd = organic or conventional; Month = January to December; Year = 2014 to 2017; Breed group = contemporary Holstein, 1964 Holstein, crossbreds sired by Montbéliarde, Viking Red, Holstein, Normande and Jersey; Parity group = primiparous or multiparous.

Table 4. Least square means and standard errors for daily activity and rumination by year across lactation numbers for the organic dairy herd and low-input conventional dairy herd

	Organic herd		Conventional herd	
Year	Mean	SE	Mean	SE
Activity, activity units				
2014	595.1[c]	15.0	530.0[c]	17.8
2015	568.7[b]	14.7	609.9[b]	14.7
2016	630.9[a]	14.6	641.4[a]	14.6
2017	635.7[a]	14.6	646.0[a]	14.7
Rumination, min/d				
2014	509.0[c]	4.2	485.5[c]	3.4
2015	515.3[b]	3.9	508.9[a,b]	3.3
2016	513.8[b]	3.9	510.5[a]	3.3
2017	522.0[a]	3.9	506.1[b]	3.3

[a,b,c]Means within a column for daily activity and rumination without common superscripts are different at $P < 0.05$.

2015 and 2016 were similar for both the ORG and CONV herds.

The least square means and standard error of means for daily activity and rumination for the ORG and CONV herd across the 4-yr study period by month are in Fig. 1. The daily activity (Fig. 1) was greater for the ORG and CONV herds in July ($P < 0.01$). Activity was the lowest during December and January for the ORG herd and lowest during December for the CONV herd. Activity increased in the ORG herd during May, which is around the time when cows are released to pasture, and therefore, may explain greater activity during this time. The ORG herd also grazed daily during the summer months from May to October, which may explain the increase in activity. The CONV herd did not increase in daily activity like the ORG herd because they did not go to pasture during May and June. Grazing cows spend a lot of their time foraging throughout the day vs. feeding from a stationary feed bunk. This could explain why daily activity was similar during the winter months (November to April) when both ORG and CONV cows were separately confined, compared to the summer months. Sjostrom et al. (2016) evaluated ORG grazing cows in a research herd and reported greater daily activity during the month of July compared to the other summer months, with lower activity in September. An increase in activity during the summer months in the CONV herd was not unexpected because the CONV herd remained confined in a dry-lot during the summer.

During the summer months, the increase in activity may be due to fly avoidance behaviors such as leg stomping or head throwing. Sjostrom et al. (2016) reported positive correlations between daily activity and flies for 100% pasture cows and pastured cows fed a partial TMR in the same herd as the current study with cows that had an HR-LD tag. Between activity and horn flies, the correlation was 0.22 ($P = 0.28$) and between activity and stable flies the correlation was 0.14 ($P = 0.10$). In grazing herds, few to no studies have evaluated increases in activity; however, the low correlations in Sjostrom et al. (2016) demonstrated a trend ($P = 0.10$) for higher activity due to stable flies and fly avoidance behaviors. Kienitz et al. (2018) reported that flies on cows may be challenging for organic dairy farms, and that farms similar to the experimental herd in the current study, would benefit from fly control methods to improve milk production and animal welfare.

For daily rumination (Fig. 2), the ORG herd had lower ($P < 0.01$) rumination time during the summer months of June and July when cows went to pasture. Lower rumination time during periods

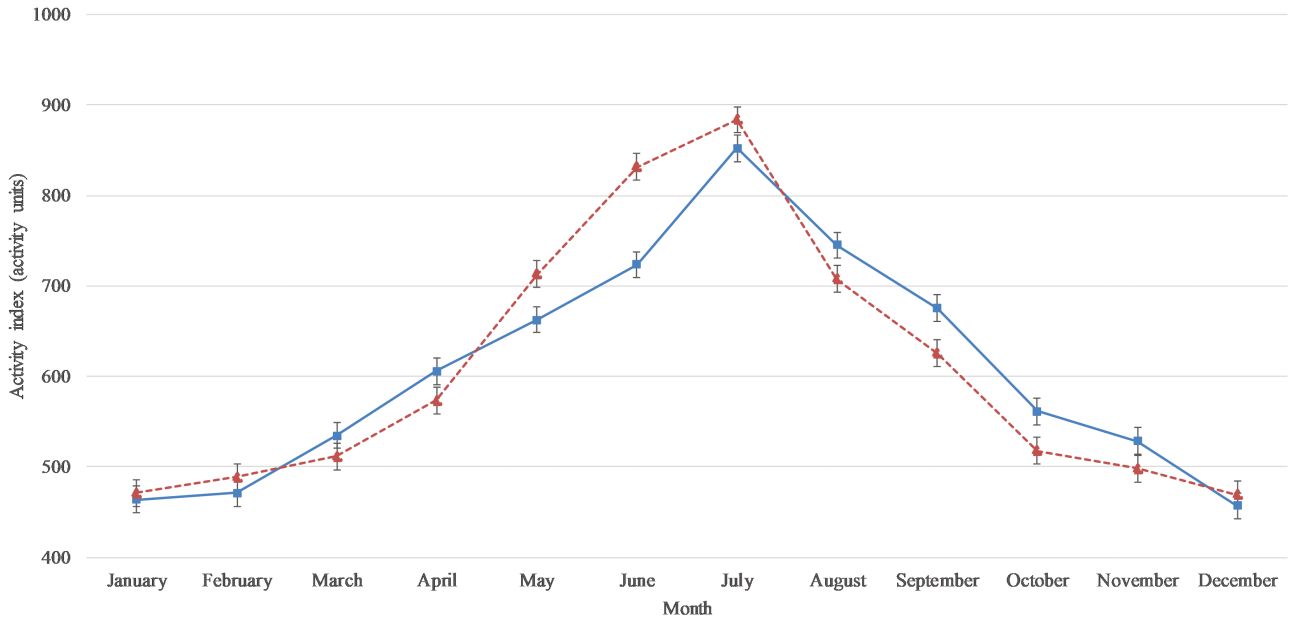

Figure 1. Daily activity index (activity units) for the organic dairy herd (▲ = ORG, red line) and the low-input conventional dairy herd (■ = CONV, blue line). Least squares means and SE bars for activity index for months averaged across 4 yr for ORG and CONV dairy cows.

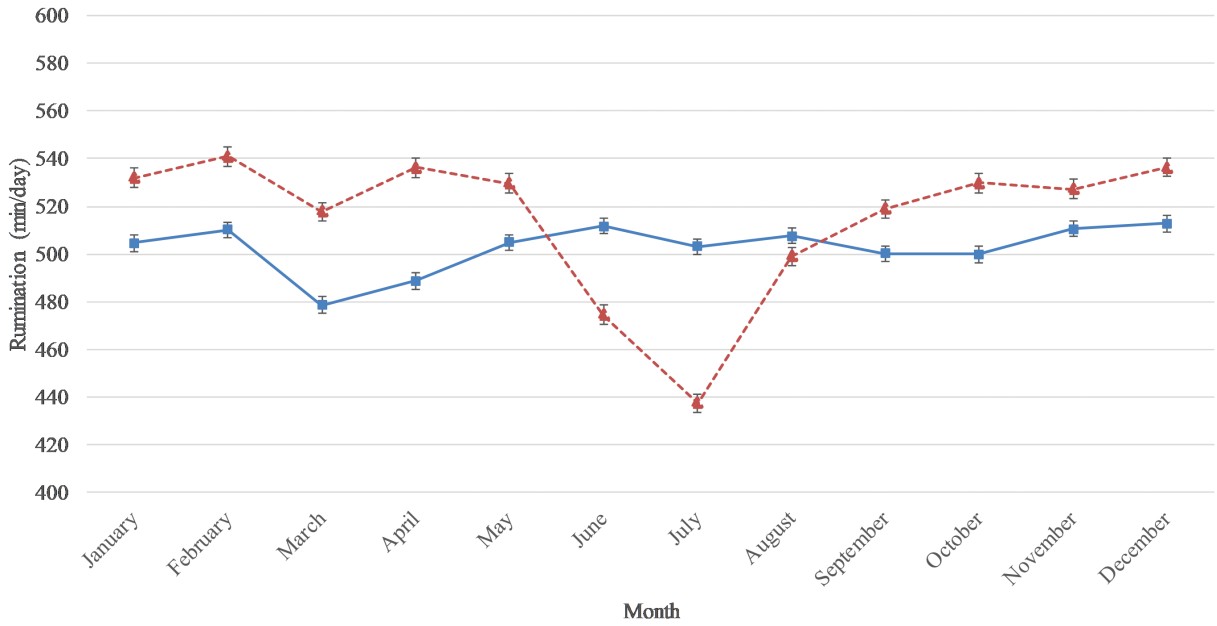

Figure 2. Daily rumination (minute per day) for the organic dairy herd (▲ = ORG, red line) and the low-input conventional dairy herd (■ = CONV, blue line). Least squares means and SE bars for rumination for months averaged across 4 yr for ORG and CONV dairy cows.

of heat stress has been documented (Soriani et al., 2013). However, the potential reason for the decrease in rumination is that grazing cows may reduce the time they spend ruminating, to optimize grazing time (Gregorini et al., 2012). The CONV herd was fed a TMR throughout the year and that could explain why daily rumination did not change as drastically for the CONV herd during the summer months. Although the current study did not compare the ORG with the CONV herd, a study in Switzerland compared eating and rumination of highland cows, fed the same hay in a winter non-grazing pasture paddock and a confined housing system. More chewing, longer ($P < 0.05$) eating (359 vs. 243 min/d) and longer ($P < 0.01$) rumination (421 vs. 373 min/d) was reported in the pasture cows when compared to housed cows. A different behavior monitoring system was used; however, the authors reported a potential reason for this was, less dominant cows were able to freely move in the pasture and had more space during feeding (Braun et al., 2014). In the current study, CONV cows had lower rumination, and space restriction during feeding

might be a contributing factor. Although various rumination times were reported in the current study, they are within range of other studies, averaging from 400 to 600 min/d (Bae et al., 1983; Prendiville et al., 2010; Braun et al., 2015; Stone et al., 2017).

Table 5 has least square means and standard errors for daily activity and rumination for breed groups by herd. For the ORG herd, daily activity was similar ($P > 0.05$) for all breed groups. For daily rumination in the ORG herd, H64 cows ruminated less (495 min/d; $P < 0.05$) compared to the HO (533 min/d), MVH (520 min/d) and NJV (512 min/d) crossbreds. Although both H64 and HO cows are purebred HO, they are genetically different. Milk production was lower for the H64 cows than the HO cows and body size is smaller for H64 cows compared with HO cows as mentioned in Hansen (2000), which may have affected daily rumination. In the current study, the BW for the H64 cows was 517 kg and 305-d milk yield was 4,910 kg, which is lower when compared to BW of the HO cows, 592 kg and milk yield 7,492 kg. Also expected, were rumination differences between HO and NJV cows as the BW and production of NVJ (499 kg) is more similar with the H64 cows than the HO.

For the CONV herd, daily activity was similar between all breed groups. For daily rumination of the CONV herd, H64 (484 min/d) cows ruminated less ($P < 0.05$) compared to the HO (513 min/d), MVH (507 min/d), and NJV (508 min/d) crossbreds. Rumination time has been described to depend on bolus size as smaller boluses take less time to chew. Bae et al. (1983), found that mastication and rumination may be affected by breed and body size. In another study, JE cows tended to regurgitate a new bolus 28 s faster than HO cows, allowing JE cows to ruminate overall for a shorter amount of time (Prendiville et al., 2010).

The rations and processing of forages varied for both herds in the current study, which may have caused some of the variation in activity and rumination time. In Table 1, ADF and NDF were greater for pasture compared to the TMR diets. During the winter for the CONV herd, the inclusion of haylage was decreased as wet beet pulp was added. A study in New York used HO cows to determine the effects of reducing dietary starch and altering carbohydrate sources on lactation performance, and reported that eating and ruminating (min/kg DMI) were greater for high-forage diets compared to high concentrate diets (Dann et al., 2015). Beauchemin (2018) summarized many studies that concluded that chemical and physical characteristics of the diet have the main impact on rumination time. In addition, the studies in the review reported that TMR diets, typically ground and chopped, could decrease rumination time (Beauchemin, 2018). A study in Italy where eight multiparous HO cows were fed high- and low-digestible alfalfa hay compared DMI and rumination time. The higher digestibility alfalfa increased DMI and rumination time (Fustini et al., 2017).

Table 5. Least square means and standard errors for daily activity and rumination by breed group across lactation numbers for the organic dairy herd and low-input conventional dairy herd

	Organic herd		Conventional herd	
Breed group[1]	Mean	SE	Mean	SE
Activity, activity units				
Holstein	612.1	44.2	583.3	20.5
1964 Holstein	629.6	26.5	597.3	35.1
MVH	582.0	21.5	611.8	15.4
NJV	607.0	15.8	634.8	38.8
Rumination, min/d				
Holstein	533.3[a]	11.6	513.3[a]	4.5
1964 Holstein	494.6[b]	7.0	483.5[b]	7.8
MVH	519.8[a]	5.6	506.7[a]	3.4
NJV	512.4[a]	4.1	507.5[a]	8.6

[a,b]Means within a column for daily activity and rumination without common superscripts are different at $P < 0.05$. There were no differences for daily activity for breeds groups in the organic and conventional herds.

[1]MVH = crossbreds of Montbéliarde, Viking Red, and Holstein; NJV = crossbreds of Normande, Jersey, and Viking Red.

Table 6 has means and standard errors for daily activity and rumination for breed groups and herd by parity group. Daily activity for the ORG and CONV herd was variable across the primiparous and multiparous HO and crossbred cows. Within the ORG herd, primiparous cows had greater activity ($P < 0.01$) in the NJV breed group (617) compared to the MVH breed group (550). Within the ORG herd, primiparous H64 cows had lower rumination ($P < 0.05$) (499 min/d) than the MVH cows (521 min/d) and all other breed groups. Within the CONV herd, daily activity was not different ($P < 0.05$) between breed groups. However, the H64 cows had lower ($P < 0.05$) rumination time (478 min/d) compared to the HO (501 min/d) and MVH (497 min/d) primiparous cows. Stone et al. (2017) used the same HR tag as the current study to evaluate HO, JE and crossbreds; however, results cannot be directly compared as the animals used in the study were in a free-stall barn. Stone et al. (2017) reported the maximum neck activity of 507 for cows during a 2-yr study period in confinement and values for daily activity as recorded by

Table 6. Least square means and standard errors for daily activity and rumination by breed group within primiparous and multiparous cows for the organic dairy herd and low-input conventional dairy herd

	Primiparous				Multiparous			
Breed group[1]	Organic herd		Conventional herd		Organic herd		Conventional herd	
Activity, activity units	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Holstein	611.3[a,b]	44.0	586.7[a]	20.5	613.0[a]	44.7	579.8[a]	20.5
1964 Holstein	522.7[a]	26.7	527.9[a]	35.3	736.5[b]	26.7	666.8[b]	35.2
MVH	550.3[a]	21.4	595.7[a]	15.4	613.8[a]	21.7	627.8[a,b]	15.4
NJV	617.4[b]	15.8	583.1[a]	38.8	595.7[a]	16.0	686.6[b]	39.0
Rumination, min/d								
Holstein	522.8[a,b]	11.5	500.9[a]	4.6	543.7[a]	12.0	525.8[a]	4.6
1964 Holstein	499.0[b]	7.1	477.9[b]	7.9	490.3[b]	7.1	489.1[b]	7.9
MVH	521.0[a]	5.6	497.1[a]	3.4	518.5[c]	5.8	516.3[a]	3.5
NJV	510.9[a,b]	4.2	498.3[a,b]	8.6	513.8[c]	4.3	516.6[a]	8.7

[a,b,c]Means within a column of primiparous and multiparous breed groups by herd for daily activity and rumination without common superscripts are different at $P < 0.05$.

[1]MVH = crossbreds of Montbéliarde, Viking Red, and Holstein; NJV = crossbreds of Normande, Jersey, and Viking Red.

the same HR tag as the current study, ranged from 262 to 396 within parity group and breed, which are lower than both herds in the current study.

For multiparous cows in the ORG herd, H64 cows had lower ($P < 0.05$) daily activity compared to the HO, MVH, and NJV cows (Table 6). Multiparous ORG H64 cows ruminated for a lower amount of time (490 min/d; $P < 0.05$) and HO cows ruminated longer (544 min/d; $P < 0.05$) than the H64 cows, MVH cows (519 min/d) and NVJ cows (514 min/d). The multiparous H64 cows had greater activity (669 $P < 0.05$) compared to HO (580) in the CONV herd (Table 6). Within the CONV herd, the H64 cows had lower rumination ($P < 0.05$) than all other breed groups. Multiparous cows tended to eat more than primiparous cows and as DMI increased rumination time also increased (Fustini et al., 2017). In addition, as cows age, chewing capacity decreases and feed particles being ingested are larger and take longer to digest during rumination compared to feed particles more efficiently broken down by younger cows (Beauchemin and Rode, 1994). Primiparous cows consumed 5 kg/d dry matter less than multiparous cows but had more rumination chews for each gram of feed consumed. Multiparous cows had longer cud chewing time, compared to primiparous cows, even though the chews per bolus were similar between parity groups (Beauchemin and Rode, 1994). These differences in rumination chews and DMI may explain some differences observed in rumination for breed groups and primiparous and multiparous cows in the current study.

In the current study, HO cows had longer rumination time. In another study with the Rumiwatch system, HO cows also had longer rumination time (458 min/d) compared to Brown Swiss cows (405 min/d) all fed the same diet (Braun et al., 2015). It has been documented that an increase in rumination may be observed from greater biting rates in higher producing cows compared to cows of lower production (Løvendahl and Munksgaard, 2016). Similarly, in another study, HO cows ruminated for 90 min more than JE cows. In the same study, JE cows had a faster passage rate and greater NDF digestibility (Aikman et al., 2008) which may affect rumination time in lactating dairy cattle. Variation in rumination time for dairy cattle may be affected by DMI, feeding management, and forage quality, milk production of cows, energy status, environmental factors, and health status of cows.

The animals in this study consisted of purebred HO and crossbred cows, which range in BW and frame size, potentially causing large variation in the results. In this study, monitoring individual feed intake was not possible, neither accounting for environmental effects such as fly populations. The HR-LD tag ARS system in the current study was installed during the autumn of 2013. The original validation for rumination in lactating dairy cattle with the same HR tag ARS system in a confinement herd was in 2008 (Schirmann et al., 2009). For grazing herds, the HR tag ARS was validated by Elischer et al. (2013) in 2011 in an automated milking system. Quite possibly, The HR-LD tag ARS system used in the current study should be re-validated under more strict grazing conditions in multiple locations within the United States. The validated studies were conducted more than 5 yr ago and algorithms or updates to programs are inevitable. Therefore, new validations should be conducted on more animals in different

enviornments to determine the effectiveness of these behavior monitoring systems. A recent validation of another behavior monitoring system in a pasture-based herd showed promise of use in grazing animals of different breeds (Pereira et al., 2018). Research on grazing and pasture-based dairy production systems in the United States is rare, and opportunity exists for more research regarding differences in environment and function of ARS across systems.

CONCLUSIONS

The activity and rumination of pasture-based and low-input dairy cows were investigated and HO and crossbred dairy cows, sired by Montbéliarde, Viking Red, Normande, and JE bulls had varying activity and rumination. The H64 cows had lower rumination time compared with the HO and crossbred cows, potentially due to body size. As the number of crossbred cows continues to rise in the United States, more research should be conducted within grazing and low-input systems. In addition, validation and re-validation of behavior monitoring systems are needed to provide producers with reliable information to manage their dairy herds. Grazing, ORG and small herd producers would benefit from behavior monitoring systems but more research needs to be conducted on how to properly use these systems in those herds.

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