Alternative Housing and Management for Organic Dairy Production

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Dedication

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LITERARTURE REVIEW

Introduction

Organic milk sales continue to grow in popularity, but the struggle for organic dairy farmers to keep up with demand lags behind. The production systems found most profitable in organic dairying may be unlike those in conventional dairy, due to rules imposed by the National Organic Program (NOP), the geographic and climatic conditions where organic farms are located, and choices by the individual organic farmers.

This review focuses on studies relating to the feeding of organic and grazing dairy cattle, including grain supplementation, activity and rumination behavior, and out-wintering. In each case, there is relatively little peer-reviewed research done on grass-fed cattle, outwintering of cattle, and measuring activity and rumination. There is even less data on these characteristics in an organic setting.

Pastured cattle in the U.S.

Although grazing on pasture is the traditional and original form of cattle management, most research in the past 40 years in the U.S. has focused on rearing dairy cattle in confinement. In North America, cattle are now commonly housed indoors year-round (USDA NAHMS 2007), or at least during the winter months, and have been since at least the 1960s (Albright and Alliston, 1971).

The 2007 USDA NAHMS survey cites 35.9% of farms and 17.8% of cows do at least some grazing, whereas 1.7% of farms and 1.2% of cows are organically certified. However, 3.1% of farms and 1.7% of cows in the study were self-selected as grazing, but not organic. Pasture-based dairies increased in Wisconsin over the past 30 years, from 7% in 1993 to 23% in 2003 (Kriegl and McNair, 2005).

The current rules of the United States Department of Agriculture's (USDA) National Organic Program (NOP) require 30% of dry matter intake (DMI) during the grazing season to be from pasture, therefore organic dairy farmers must send their cattle to pasture for at least 120 days a year. Whether or not supplementing grain to organic cattle is advantageous depends on price and region of the country. Organic corn prices are higher than conventional corn prices, and more prone to shocks in supply and demand (Singerman, 2014).

Auldist et. al (2011) found that even cattle on pasture in extended lactations up to 22-months will have a higher feed conversion efficiency when supplemented with grain. The study used wheat and triticale as supplements, testing feed efficiency and marginal milk over time. The study found that feed efficiency was higher with grain supplementation both at 60 and 530 days in milk (DIM), but margin milk did not change.

In the rumen, Reis and Combs (2000) concluded that more grain supplementation increased metabolizable energy intake without a loss of DMI. Simultaneously, milk production, milk protein and yield, and solids-non-fat concentration in the milk increased. The study utilized a 50% grass and 50% legume pasture mix with only 9 rumen-cannulated Holstein cows averaging 41.6 kg of milk per day, blocked by days in milk with an average DIM of 84. Cows were fed 0, 5 or 10 kg of concentrate, which consisted of dry shelled corn. In that study, cows were on pasture for 20 hours. Those cows receiving only pasture produced 18.7% and 28.3% less milk than cows fed 5 and 10 kg of concentrate, respectively.

Bargo et. al. (2002) utilized 20 multiparous Holstein cows in five 4x4 Latin squares using two pasture allowance levels, 25 versus 40 kg DM/cow/day, and two concentrate levels, 0 versus 1 kg per 4 kg of milk. Concentrate decreased pasture supplementation in the study; however, the higher level of concentration saw a less marginal increase in kg of milk per kg of concentrate. In a follow-up study based on economics, the researchers found a highest income over feed costs (IOFC) for cows fed the lower pasture allowance with concentrate supplementation.

Bargo et. al. (2006) compared 100% pasture to pasture plus TMR or all TMR, with 45 Holstein cows. Milk yield was highest for 100% TMR, and lowest for 100% pasture. A follow-up of the economics found the 100% TMR treatment had the best income per kg of milk due to higher milk yields and higher components.

Bargo et al. (2003) found a linear relationship with milk production when increasing concentrate from 1.2 to 10 kg DM/day and milk gains at a rate of 1 kg milk/kg concentrate. But each kg of concentrate represented 12 minutes less of grazing time.

Washburn and Mullen (2014) found in a review that a pasture-based sire index could be helpful for U.S. producers, especially based on the experience of graziers in other countries. They noted that daughters of bulls from New Zealand outperformed U.S.-born Holstein sires in somatic cell score, but not in days open, milk production, or protein from a presentation by Norman et al. (2006).

Summary:

The literature above finds that organic and grazing herds are a small percentage of U.S. dairies, and that grazing will typically produce less milk than grazing plus a concentrated supplement. However, although the USDA-NAHMS study is a good general representation of the dairy industry, it only selected dairy farms from 17 of the nation's major dairy states, representing 79.5% of dairies and 82.5% of cows at the time.

The missing states could be more likely to graze, especially considering that the entire Southeastern U.S., Oregon, and much of the Central Plains were excluded. But generally, organic and grazing herds have continued to be a small portion of the herds, and even smaller portion of the cows, in the United States.

The Australian study (Auldist et al., 2011) did not use corn, one of the most readily-available organic grains available in the U.S., due to its high-yielding characteristics near conventional corn. Despite this, the findings are consistent with the Combs study that milk production was higher. Although the Combs study used just 9 animals, the in-depth analysis through cannula found very precise results in terms of what was happening inside the rumen of the grazing cattle.

The Wisconsin (Reis and Combs, 2000) and the Penn State review (Bargo et al., 2003) studies showed consistent results with each other, namely, that higher levels of TMR or concentrate equals more milk, and Bargo et al. (2003) showed more milk equaled more profit in each case. However, each of these studies were with purebred Holstein cattle, not with the cross-bred style cow often found in an organic system in the U.S. as referenced in Washburn (2014). Washburn concluded that pasture-based systems using crossbreeding can have advantages, especially in a seasonal environment. The studies also did not take into consideration what organic corn prices would have been, which can be between 1.5 and 2.5 times the price of conventional corn, and can change the economics significantly as corn or corn silage is replaced by organic hay, creating a domino effect.

No study referenced comparison of crossbred animals on grass versus supplementary systems, though some of the animals in our study are Holstein-sired and may share some similar traits. No study has compared supplementation in the Upper Midwest near the University of Minnesota's West Central Research and Outreach Center, with its unique topographic setting, mixture of grasses and climate.

The studies point to pasture-based dairying continuing to become popular in the United States. While TMR and concentrate additions result in more milk per cow, greater DMI per cow, and profit in certain scenarios, it is unknown whether it will always be the case for organic dairy production with the pasture rules as they are. Our study will help to compare a 100% grass diet to one supplemented with grain, and future research will look to add economics into the equation.

Activity and rumination of dairy cattle

Activity and rumination systems (ARS) that detect estrus and health events are growing in interest by dairy farmers looking to replace on-farm labor and also increase technology that can help keep cows healthy. Farmers interested in precision technology are especially interested in mastitis, standing estrus, and daily milk yield (Borchers and Bewley, 2015).

Automatic activity systems for heat detection have been studied since at least 1976, when Kiddy explored activity with pedometers on 68 cows, 40 in freestalls and 28 in comfort stalls (Kiddy 1976), finding that activity increased four times during estrus over activity when cows were not in estrus, and concluding it could be an aid for estrus detection.

In the mid-2000s, ARS became available for sale in the United States. Several systems have been introduced and upgraded.

In 2009, Schirmann et. al. validated the Hi-Tag, SCR Engineers Ltd., Netanya, Israel, for rumination, using visual observations to compare with 27 Holstein cows. The system was highly correlated (r = 0.93, R2 = 0.87, n = 51) with the direct human observations, and determined to be a useful tool for monitoring rumination in dairy cows. The researchers did note errors based on placement of the tags and collar on the neck of the animal.

Kamphuis (2012) found that the activity numbers produced by the SCR monitors were a useful tool on a large pasture-based system in New Zealand, placing monitors on 635 cows during their breeding period. They tested both activity only collars (AO) as well an ARS collar. At the time, they found the AO and ARS to perform well below manual detection, but noted that due to study design and estimating date of estrus the results could be much higher than calculated.

In 2013, Elischer et. al. were the first to test the ARS for both rumination and activity in conjunction with their automatic milking system (AMS) on pasture. To test it, they utilized live observations as well as a previously validated pedometer, the IceQube (IceRobotics, Edinburgh, UK). The study used 15 cows with pasture access milked in their AMS, and found that while the monitors recorded activity and rumination accurately, there was no way to break out walking, standing, or lying behaviors. The researchers also warned that rumination could not be fully validated due to inaccurate placement of the rumination monitor and interference from other signals.

One group of researchers evaluated activity using a different device (Kenz Lifecorder LCEX; Suzuken Co. Ltd., Nagoya, Japan) to match grazing time with activity. In addition to validation of activity and rumination, several studies have evaluated ARS accuracy at estrus detection (Ueda 2011, Homer 2013, Stevenson 2014, Ambriz-Vilchis

2015, Silper 2015) and for events beyond estrus like health (Aungier 2012, Aungier 2015) and calving (Schirmann 2013, Calamari 2014).

Neves (2015) conducted a survey to evaluate how producers might be using AO systems, finding that producers had variable results with reproductive management after installing the systems, but average pregnancy risk increased from 15% to 17% and insemination risk increased from 42% to 50%.

Summary

Although these studies have tested and validated cows in AO and ARS collar situations, only one has done them in a large herd type situation as experienced in our experiment where interactions between animals may differ with the other experiments, most had fewer than 50 purebred Holstein cows, and those where involved in confinement. Our experiment will have nearly 80 cows involved over two years, across different genetic groupings, and being housed outdoors during the winter months.

Further, engineers with SCR Ltd. continue to upgrade both the hardware and software that make up the Heattime ARS (Heim Fleminger, 2013, personal communication).

Therefore, each experiment needs to be judged on its own accord, relatively speaking. In our initial testing of the technology, something seemed to be causing inaccuracies in heat detection, far higher than explained in the literature above. After some consultation with the company, activity levels were adjusted to make the software more useful for farm-level management and detection of estrus (Heins, 2013, personal communication).

Kamphuis (2012) did a large scale experiment with 635 cattle in a grazing environment, but as proprietary information continues to update within the software and hardware of these systems, it is difficult to know how to compare one study to another.

Outwintering dairy cattle

Outwintering is typically a term used for beef cattle in the U.S., as cattle can graze corn stalks and the leftover corn cobs not picked by the corn combine in the Upper Midwest.

However, some research has been done in Ireland and New Zealand, although winters are much milder than in the Upper Midwest U.S. There is no known outwintering research with dairy cattle in any region of the United States.

Cows spent less time lying down, had higher cortisol, glucocorticoid, T4 and NEFA concentrations when kept outside in a study in the Zealand, where Tucker (2007) noted that the 20 cows in the study reduced surface area exposed to the wind and the rain. Cows with more body condition were also better prepared for effects of winter weather, they concluded. A weather station recorded temperatures, wind chill and precipitation every 10 minutes. Body condition scores were taken on a scale of 1 to 10, and researchers took behavioral measurements for a full 24 hours every 10 minutes three days per week. Overall, authors concluded that shelter clearly improves animal welfare in the New Zealand winter.

Several other outwintering papers come from Ireland. Boyle et al. (2008) used 96 yearling heifers raised indoors in freestalls with cow mats and sawdust and lime for bedding compared to cows outdoors on woodchips in a 2x2 factorial arrangement fed either grass silage or grass silage with 3 kg of concentrates. The research showed fewer lesions outdoors, dirtier animals, and lower feed intakes resulting in lower BCS and average daily gains. The research took place at the Moorepark Dairy Production Research Centre, Fermoy, Ireland, in the winter of 2004-2005. Researchers measured body condition, energy, body temperature, hair length, meteorological data, activity (feeding, ruminating, active, and sleep), posture (ventral lie, lateral lie, and stand) and location (lying area and concrete) along with lesions, and behaviors. However, as these were unfresh heifers there was no milk production data. Temperatures averaged 7.1°C, reaching as low as -3.8 °C and up to 13.8°C, with 2.3 mm rainfall in a four month period. Indoor heifers grew at faster rates and had higher feed intakes than outdoor heifers, but both groups' growth rates were above their targets of 0.6 to 0.7 kg per day as recommended in Ireland.

O'Driscoll et al. (2009) used 147 pregnant cows in 49 blocks of 3 animals in rubber mat freestalls, uncovered outdoor woodchip housing, or covered outdoor woodchip housing. Outdoor woodchips offered more cushion and less injury, though rained-on woodchips may have led to higher sole lesion development.

Summary

In the six week trial by Tucker in New Zealand temperatures reached only a low of -3.1 °C compared to -14.4 °C in our trial. The maximum temperature did reach 12.7 °C, which could be achieved during a winter at the West Central Research and Outreach Center where our trial was completed. Our trial did not record behavioral measurements at any point in time.

The pieces of Irish research pertain to a region with winters that do not compare to those in the Upper Midwest U.S. in terms of minimum temperatures. Boyle et al (2008) determined that outdoor housing was a "good alternative" to wintering in freestalls. Heifers indoors grew at higher daily weight gains than those outdoors, but the feed was ultimately different as outdoor feed was rained on while indoor feed was protected in the study.

One potential lower-cost barn system is a compost-bedded pack barn, as described in Barberg et al. (2007a, 2007b). These barns provide three-sided wind protection and can be open to an indoor or outdoor feeding area. The compost-bedded pack barns can use a combination of or single organic bedding source(s), such as dry fine wood shavings, wood chips, or sawdust. Minnesota compost bedded pack barns were built for cow comfort, cow longevity, and ease of chores according to survey results in Barberg et al. (2007a). Producers said the bedding required special attention during milking preparation, and also saw issues with air quality and dust.

In Barberg et al. (2007b), these barns averaged \$33,000 to \$300,000 in cost, with cost per cow ranging from \$625 to \$1,750, and the variable cost of sawdust did concern some dairy producers at the time.

Black et al. (2013) reported improved cow cleanliness and high satisfaction in a survey of dairy farmers using the facilities in Kentucky. Farmers reported an increase in milk production from before moving into new compost bedded pack barn facilities into their second year of use (from 29.3 to 30.7 kg/day, n=8). The calving interval also decreased in the survey, from 14.3 to 13.7 mo (n=8).

Black et al. (2014) took bedding samples from 42 compost-bedded pack barns and found that the environment contained in an actively composting compost-bedded pack barn is the same environment in which mastitis thrive.

Four other Irish studies (O'Driscoll et.al (2008a), O'Driscoll et. al. (2008b), O'Driscoll et. al. (2009), and O'Driscoll et. al (2010)) also could recommend outwintering pads and freestalls with mats in similar results for dry and lactating cattle based on hygiene, locomotion, and lying behavior tracking. None of these trials involved cows that had ARS collars.

One case study from Posner et al. (2008 does feature a straw-based compost bedded pack barn with a cement floor and outside feeding area. However, there were no measurements of the bedding surface to allow statistical evaluation of cause and effect. The farm held somatic cell count lower, under 400,000, for the three years following the building of the shelter than the three years prior, but somatic cell count again hit over 500,000 and 600,000, where large portions of the herd have infections in their mammary glands.

CONCLUSIONS

Grazing management continues to be a system in the United States that requires more study, especially in a northern climate like the Upper Midwest. While more milk production is almost always achieved through utilizing grain components or a TMR, producers need to weigh the economics and labor of a feeding system with allowing cows to graze and therefore collect feed on their own.

Although there is some literature pertaining to utilizing ARS collars on cows in grazing systems, little is known how to utilize the ARS to manage cattle. ARS studies have mostly been done with less than a few dozen cattle and the management uses are only beginning to be explored. As ARS continue to evolve, they may become more useful for grazing operations in the U.S., but due to unique situations that may include walking, fly pressure, or the way grass is consumed on pasture, activity may need to be adjusted specially for grazing herds.

The Irish dairy studies cite outwintering pads using woodchips, a practice often replaced with wheat or oat straw in the United States and in our study.

In Black et al. (2013), cow comfort and milk production improved in the eyes of the dairy farmers using compost-bedded pack barns, but the survey came from barns of different arrangements and procedures, with variability in both compost management and parlor preparation procedures between farms.

In Black et al. (2014), the importance on good milking procedures was stressed due to the findings that showed the composting environment is similar to the environment in which mastitis bacteria thrive. Both studies show the potential for spreading mastitis bacteria, which may be better or worse in the colder Minnesota climate during the winter time. Continuous air temperatures were not taken with either study.

The Posner et al. (2008) study does give an example of a successful barn with a straw pack; however, it is not known what effect the barn had to success of the farm. There have been no studies of an unsheltered outdoor straw pack in relation to rumination, activity, hygiene, milk production, somatic cell count, or lesions to the knowledge of the author.

Finally, there is no known literature on outwintering lactating dairy cattle in a climate similar to that found with the cold winters of the Upper Midwestern United States. Data from other countries shows that cows do make adjustments for the cold and that shelter and higher body condition scores can help mitigate the cold, but the low temperatures experienced in Minnesota winters are yet to be scientifically evaluated.

SHORT COMMUNICATION:
ACTIVITY AND RUMINATION OF ORGANIC DAIRY CATTLE

Short communication: **Effect of organic grain supplementation on activity and rumination time and pasture fly activity of organic dairy cows.**

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SUMMARY

Organic cows (n = 57) were used to evaluate activity, rumination time and their correlation with pasture fly activity of cows fed 3 grain supplementation strategies during the grazing season from May to September 2013. Cows were assigned to 1 of 3 replicate supplementation groups: 1) no corn grain supplementation (100% pasture, GRASS, n = 19), 2) low corn grain (2.72 kg/head/day, LO, n = 19), and 3) high corn grain (5.44 kg/head/day, HI, n = 19), and calved during 2 seasons (fall and spring) at the University of Minnesota West Central Research and Outreach Center, Morris, from October to December 2012 and March to May 2013. Supplement (organic corn grain and minerals) was fed with a TMR of corn silage and alfalfa silage, and at least 30% of diet DMI for LOW and HI cows consisted of organic pasture. Activity and rumination time (daily and 2-h periods) were monitored electronically using HR-LD Tags (SCR Engineers Ltd., Netanya, Israel) for 125 days. Activity is reported in “activity units” from SCR DataFlow II software. The PROC HPMIXED of SAS was used for statistical analysis, and independent variables were season of calving (fall or spring), month of grazing (June to September), parity (1, 2, 3+), supplementation group and the interactions of month of grazing and supplementation group, and parity and supplementation group. Cow and replicate were random effects with repeated measures. The GRASS (1,138) cows had greater daily activity than HI (1,001) cows, but were similar to LO (1,019) cows. Daily activity was greatest during July (1,258) and least during September (819). Rumination was not different for the GRASS (397 min/d), LOW (384 min/d), and HI (370 min/d) cows. Daily rumination was greater during September (402 min/d) compared to July (361 min/d). Daily activity increased rapidly from h 6:00 and 8:00 to h 16:00 and 18:00.

From h 18:00 to 20:00, cows had a rapid decline in activity until h 6:00 the next day. All supplementation groups had the greatest rumination during h 2:00 and 4:00 and the least during h 10:00 and 12:00. Greater activity of cows on a herd basis was moderately correlated with increased pasture fly prevalence. Monthly activity and rumination patterns of grazing organic cows may have been influenced by the weather and fly populations.

Key words: activity, rumination, organic, grass-fed

Short Communication

Activity and rumination monitoring systems (ARS) are growing in popularity in the global dairy industry. Because of rapid development of precision dairy technologies, these monitoring systems are more feasible for dairy producers to adapt into their management enterprise. However, producer perception of these ARS systems is widely unknown (Borchers and Bewley, 2015).

The ARS systems may assist small and organic dairy producers achieve superior pregnancy rates without the use of reproductive hormones and identify unhealthy cows on dairies. These systems may be beneficial to small organic dairy herds where labor may not be available to watch cows for mounting behavior, and especially for U.S. organic dairies, who are not allowed to use reproductive hormones as part of their management procedures (USDA-NOP, 2015).

Predominately these ARS systems are installed in confinement dairy operations, and very little research has been conducted in grazing environments; however, a few studies have been conducted in New Zealand (Kamphuis, et al, 2012, Elischer et al, 2013; Gregorini et al. 2013). Schirmann et al. (2009) reported ARS systems accurately measure of rumination time of cattle. Elischer et al. (2013) found ARS systems reflect cow walking and rumination in a pasture-based dairy herd in the US, but not with high accuracy. Furthermore, the ARS activity index does not distinguish between walking and lying behavior (Elischer et al., 2013). For pasture-based dairies, cows regulated their rumination time to compensate for management styles that restricted grazing time (Gregorini et al., 2012), and daily rumination was not different for alternative breeds of cows and cows with varying genetic merit on pasture (Gregorini et al., 2013).

The horn fly is an important pest of pastured dairy cattle, because the flies decrease milk production and reduce pasture intake of cattle (Denning et al., 2014). Furthermore, horn flies and stable flies reduce milk production and overall farm profitability (Taylor et al., 2012; Mays et al., 2014). Pasture fly control measures are applied on 89% of organic dairy herds in Minnesota (Sorge et al., 2015); however, fly management of pastured cattle is a growing problem, and many farmers rely on essential oil repellents to alleviate fly problems. Pasture cattle will exhibit many different fly avoidance behaviors that include head tossing, foot stomping, and bunching, which can lead to decreased grazing time (Hart, 1994). Pasture flies may also affect the movement of the neck-collar-attached ARS systems; however, no research has determined the effect of flies on activity and rumination in a pasture-based grazing system.

Specifically, the objectives of this study were to determine differences between organic dairy cows fed 3 supplementation strategies during the grazing season for activity and rumination and correlate activity and rumination with pasture fly activity from an automatic activity and rumination monitoring system.

Fifty-seven organic dairy cows from the University of Minnesota West Central Research and Outreach Center, Morris, Minn., were split into 3 replicated groups (2 replicates per supplementation group) grazing side-by-side during summer 2013. Cows were fed the following dietary supplementation levels, 1) no grain supplementation (100% pasture, **GRASS,** n = 19 cows), 2) low grain (2.72 kg of grain supplementation per day, **LO,** n = 19 cows), or 3) high grain (5.45 kg per day, **HI,** n = 19 cows). Supplement was fed with a total mixed ration of an organic grain mix (corn and minerals). Cows supplemented were fed a partial TMR that included organic corn silage, alfalfa silage, and the corn-grain mix. On an as-fed per cow per day basis, the TMR was 11.34 kg pounds of organic corn silage, 7.26 kg of organic alfalfa silage, and 0.66 kg of organic minerals. The partial TMR was fed in a compost barn after the morning milking, but LO and HI cows were allowed to graze during the afternoon and overnight. The GRASS cows were continually on pasture except during milking. Furthermore, for all cows, at least 30% of their diet consisted of high-quality organic pasture during the grazing season. All 6 groups of cows grazed alongside each other in the same pasture, consisting mainly of smooth bromegrass, orchardgrass, timothy, alfalfa, and red and kura clover. Cows were moved to pasture on May 28, 2013 and grazing ended September 30, 2013. All groups of cows were simultaneously rotated to new paddocks every 2 days based on forage availability that was determined through visual observation or a Filip's electronic rising plate meter (Jenquip, NZ Agriworks Ltd., Feilding, New Zealand).

All 57 animals were fitted with an HR-LD activity and rumination monitoring collar (SCR Engineers, Netanya, Israel) around the neck (Schirmann, et al., 2009). Due to manufacturer's settings, the ARS collect data for 7 d before calculating a baseline activity and rumination index. The monitors hold 24-hours of data and correspond with a long distance (LD) antenna placed atop the milking center. The antenna had a range of several hundred meters depending on the weather and other environmental factors. Each time the cattle returned to the milking center, and if they were in paddocks nearby the milking center, the antenna would download data as often as every 20 min. Cows were milked in a swing-9 parabone milking parlor at 06:00 and 17:00.

Fly presence was counted on every cow on Mondays during the grazing season between 1300 h and 1500 h by trained observers. The observers identified horn flies (*Haematobia irritans irritans*), face flies (*Musca autumnalis*), and stable flies (*Stomoxys calcitrans*) until all cows were identified. Horn flies were counted individually over one side of the back, or in groups of 10 when the population was excessive. Stable flies were counted on both the front and rear legs. Fly densities on cows were determined by counting the number of flies on a cow from a distance of 2 to 4 m (Watson, et al., 2002; Denning et al., 2014)

Independent variables for statistical analysis of daily activity, daily rumination, activity at 2-hr intervals, and rumination at 2-hr intervals were effects of month, parity, supplementation group, and the interactions of month and supplementation group, and parity and supplementation group. Additionally, cow and replicate were random effects with measurement date as repeated measures. For activity and rumination at 2-hr intervals, 2-hr time block and the interactions of 2-hr time block and supplementation group, and 2-hr time block and mo and supplementation group were added to the model. The autoregressive covariance [AR(1)] structure was used because it resulted in the lowest Akaike's information criterion (Littell et al., 1998). The HPMIXED procedure of

SAS (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 $P < 0.05$.

For the analysis of fly activity, Pearson correlation coefficients were calculated using PROC CORR procedure of SAS (SAS Institute, 2014). Daily activity and rumination were paired with number of flies observed on cows based on counting observations every Monday during the grazing season.

Least squares means and standard errors for daily activity and rumination for grazing month and supplementation group are in Table 1. For daily activity by month across supplementation groups, cows in July (1258) had greater ($P < 0.05$) activity than cows in June (1032), August (1101), and September (819). For daily rumination, cows in September (402 min/d) had greater ($P < 0.05$) rumination time than cows in June (377 min/d), July, (361 min/d), and August (395 min/d). Daily activity rose from June to July, then fell in August and through September to its lowest level. Conversely, rumination decreased during July; however, rumination increased during August and September. Throughout the duration of the current grazing study, the correlation of daily activity and rumination was -0.60.

For supplementation groups across months, the GRASS cows had greater ($P < 0.05$) daily activity (1138) compared to the HI (1001) cows, simply because they were on pasture longer during the day as more DMI was consumed on pasture for the GRASS cows. The LO and HI cows were not different for daily activity. Surprisingly, daily rumination was not different for the supplementation groups, and averaged from 370 min/d for the HI cows to 397 min/d for the GRASS cows. The results from the current study for daily rumination are lower than those reported by Gregorini et al. (2013); however, the differences are likely attributed to the differences in grazing systems and grass species in pastures between New Zealand and the US.

The least squares means and standard errors for daily activity and rumination for grazing month and supplementation group are in Table 2. The GRASS cows had greater ($P < 0.05$) daily activity during June, August, and September than the LO and HI cows. Possibly, fly numbers were greater for all cows during July, and therefore, there were no differences between supplementation groups for daily activity. The GRASS cows may have been expected to have greater activity because of more frequent walking to the milking parlor on average and the need to consume un-grazed pasture within a paddock. Daily rumination by month was not different for supplementation groups. Although not statistically different, numerically the GRASS cows also had greater rumination than the LO and HI cows during the summer grazing months. The reason for the varying daily activity and rumination among months may be due to feed availability, ambient temperature, weather events, fly pressure, or other factors. Furthermore, the difference among supplementation groups is likely because of amount time spent grazing and a greater percentage of DMI coming from pasture for the GRASS cows.

Figure 1 has means for activity by 2-h intervals and Figure 2 has means for rumination by 2-h interval for GRASS, LO, and HI supplementation groups. All cows increased in activity from 04:00 to 06:00 h throughout the day until 18:00 h. The GRASS cows had greater activity ($P < 0.05$) during the early morning and early evening hours because of the movement to the milking parlor and back to the grazing paddock. Activity levels decreased tremendously at 18:00 hours and remained low until 04:00 h.

For rumination across 24 h (Figure 2), the GRASS cows had greater ($P < 0.05$) rumination from 02:00 h to 04:00 h than the LO or HI cows. Surprisingly, the LO cows had greater ($P < 0.05$) rumination per hour from 10:00 h to 14:00 h than the GRASS or HI cows, and explanation may be unknown because LO and HI cows were in the same feeding and housing environment during the day. All of the supplementation groups ruminate during the night and remain active during the day (Figure 1 and 2), possibly reversing the notion that the GRASS cows would rest during the extreme hot portion of the day and consume more DM during the night. Nonetheless, the results are similar to Gregorini et al. (2013) who reported cows grazing during the spring months in New Zealand had greater rumination per hour during the night and early morning compared to during the day.

Correlations of daily activity and rumination and numbers of pasture flies on cows are in Table 3. An increase in number of horn flies did not increase activity levels for GRASS cows; however, a greater number of horn flies on LO and HI cows increased ($P > 0.05$) activity of the cows. An increase in horn fly number may not have affected the GRASS cows compared to the LO and HI cows because the GRASS cows grazed more during the day compared to LO and HI cows. For daily rumination, an increased number of horn flies on cows decreased ($P < 0.05$) rumination of the GRASS cows ($r = -0.48$). The number of face flies and stable flies on cows did not affect daily rumination of all 3 supplementation groups. The effect of increased number of pasture flies on rumination was expected to be greater than reported; however, rumination in cows was greatest during the evening hours when fly pressure is not expected to be at high levels. Daily activity was more affected by increased fly numbers. Boland et al (2008) reported an increase in fly avoidance behaviors with increase fly pressure. Possibly, the ARS was detecting fly avoidance behaviors (i.e. head throws) instead of detecting actual grazing activity of cows. Decreasing fly pressure should promote animal well-being and decrease fly avoidance behaviors, as well as increasing grazing time of cows.

Results of this study suggest increased daily activity of cows that spend most of their day on pasture; however, daily rumination was not different between cows that consumed 100% pasture compared to cows that were supplemented on pasture with a partial TMR. An increase of pasture fly activity increased activity and decreased rumination of dairy cattle on pasture and this may lead to reduced production and decreased animal well-being of grazing dairy cattle.

Therefore, organic dairy producers must carefully design grazing management, facilities, and nutritional feeding systems to ensure maximum productivity and well-being of organic dairy cattle.

Dairy producers with organic management may evaluate whether ARS systems are useful for their dairy herd. Identifying the daily grazing patterns of cows on pasture versus those fed concentrate indoors will help discover health and reproductive events much earlier, leading to a more profitable dairy herd. Further evaluation of pasture fly activity and cow health with activity and rumination should be conducted.

ACKNOWLEDGEMENTS

The authors express gratitude to Darin Huot and coworkers at WCROC for their assistance in data collection and care of animals. Financial support was provided for this project by The Ceres Trust (Chicago, IL) and by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2012-51300-20015.

Table 1. Least squares means and standard errors for daily activity and rumination for grazing month and supplementation group.

	Daily activity		Daily rumination	
	Mean	SE	Mean	SE
	---- (activity units)----		---- (min/d)----	
Month				
June	1032[a]	30.9	377[a]	16.7
July	1258[b]	30.9	361[b]	16.7
August	1101[c]	31.2	395[c]	16.8
September	819[d]	31.7	402[d]	16.9
Supplementation group				
100% pasture	1138[a]	44.1	397	24.3
Low supplementation	1019[a,b]	66.7	384	36.7
High supplementation	1001[b]	41.5	370	22.9

[a-d]Means within a column for month and supplementation group without common superscripts are different at $P < 0.05$.

Table 2. Least squares means and standard errors for daily activity and rumination for grazing month and supplementation group.

	100% Pasture		Low Supplement		High Supplement	
	Mean	SE	Mean	SE	Mean	SE
Daily activity[1]						
June	1175[a]	46.1	985[b]	67.8	935[b]	43.5
July	1280	46.1	1264	67.9	1230	43.6
August	1189[a]	46.3	1053[b]	68.5	1063[b]	43.9
September	907[a]	47.4	777[b]	69.0	775[b]	45.1
Daily rumination[2]						
June	380	24.8	373	36.9	378	23.3
July	380	24.8	357	36.9	344	23.3
August	412	24.8	396	37.1	376	23.4
September	417	25.0	408	37.2	382	23.7

[a-c]Means within a row for daily activity without common superscripts are different at $P < 0.05$.

[1] Activity is presented as “activity units”

[2] Rumination is min/d

Table 3. Pearson correlation coefficients of daily activity and rumination and numbers of horn, face, and stable flies for supplementation groups.

	100% Pasture		Low supplement		High supplement	
	Correlation	P-value	Correlation	P-value	Correlation	P-value
Daily activity						
Horn Flies	0.22	0.28	0.61	0.001	0.40	0.05
Face Flies	-0.06	0.59	0.02	0.94	-0.28	0.16
Stable Flies	0.14	0.10	0.43	0.03	0.33	0.10
Daily rumination						
Horn Flies	-0.48	0.01	-0.25	0.21	-0.04	0.86
Face Flies	0.25	0.21	0.13	0.54	0.27	0.18
Stable Flies	-0.23	0.26	0.31	0.11	-0.15	0.46

Figure 1. Activity index of GRASS, LO, and HI cows in two-hour increments.

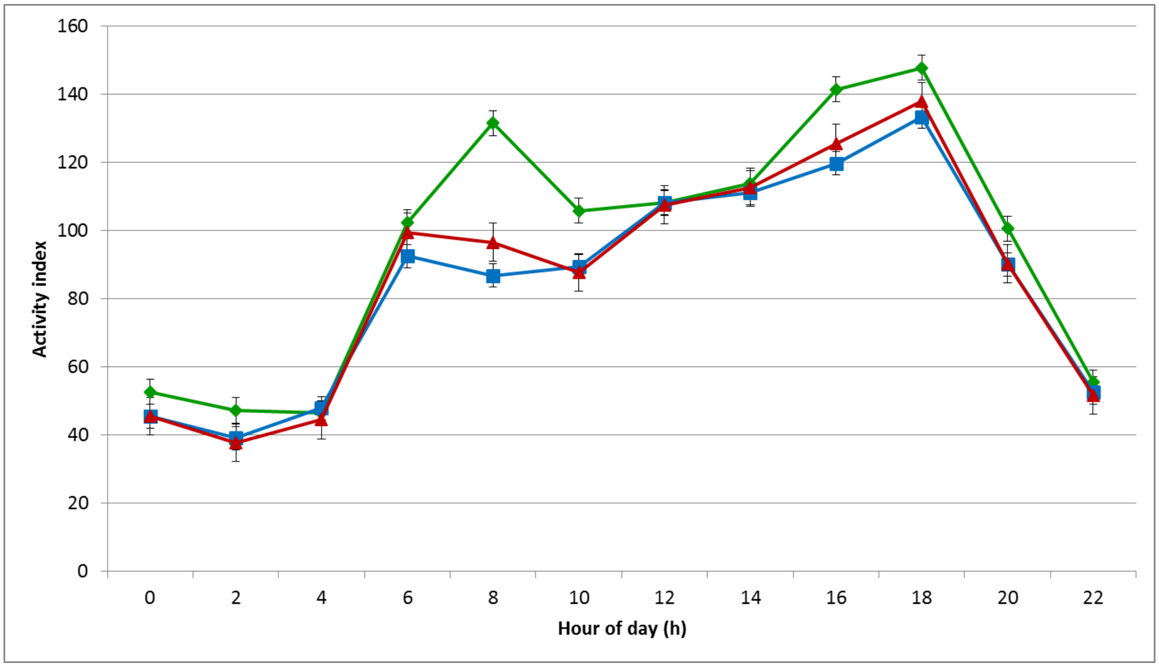

Figure 2. Rumination time of GRASS, LO, and HI cows in two-hour increments.

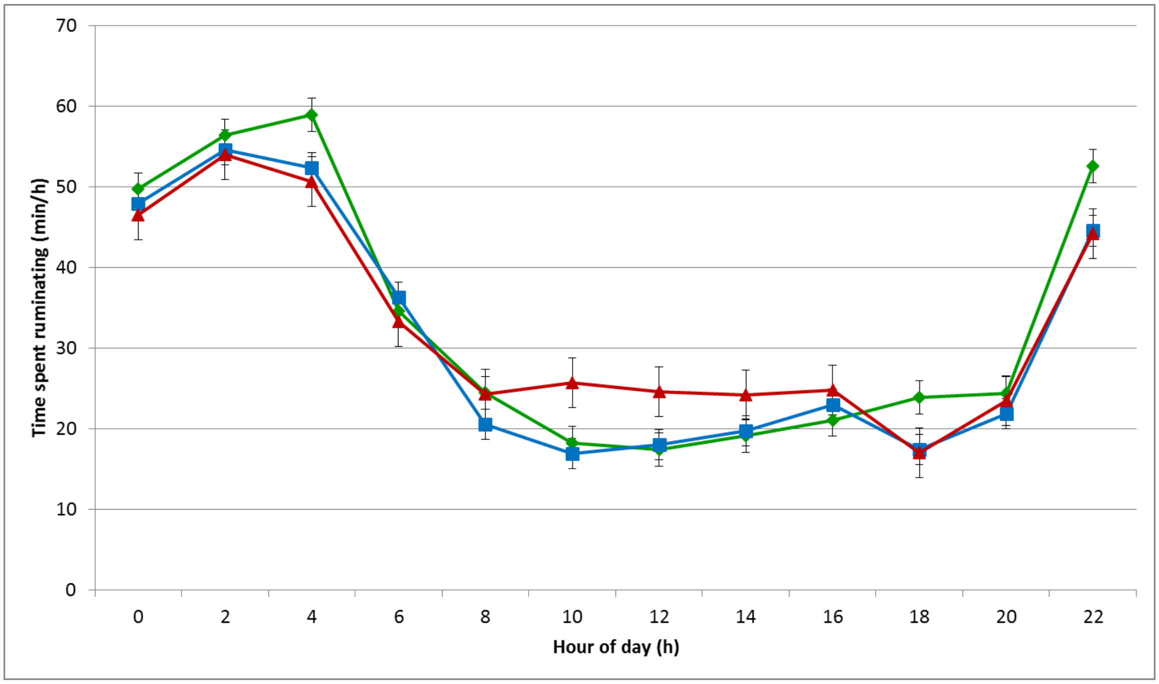

Figure 1. Least squares means for activity index by 2-h intervals for GRASS, LO, and HI supplemented organic dairy cows (♦ = Grass cows, ▲ = LO supplemented cows, ■= HI supplemented cows).

Figure 2. Least squares means for rumination (min.) by 2-h intervals for GRASS, LO, and HI supplemented organic dairy cows (♦ = Grass cows, ▲ = LO supplemented cows, ■= HI supplemented cows).

BEHAVIOR AND RUMINATION OF OUTWINTERING ORGANIC DAIRY COWS

Effects of winter housing systems on hygiene, udder health, frostbite and rumination of organic dairy cows

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SUMMARY.

Certified-organic cows (n = 82) were used to evaluate the effect of two winter housing systems (December 2013 to April 2014) on hygiene scores, frostbite, teat condition, clinical mastitis, and activity and rumination. Cows were assigned to two treatments (two replicates per group): 1) outdoor (straw pack, n = 39) or 2) indoor (3-sided compost-bedded pack barn, n =43). There were 20 and 19 cows per replicate for the outdoor housing and 22 and 21 cows per replicate for the indoor housing. Cows calved during two seasons (spring or fall) at the University of Minnesota West Central Research and Outreach Center, Morris, Minnesota, organic dairy. Organic wheat straw was used as bedding for the 2 outdoor bedded packs and were maintained by farm management to keep cows dry and absorb manure throughout the winter. The open-front compost-bedded pack barn (2 pens in the barn) was bedded with organic approved sawdust, and the bedding material was stirred twice per day with a small chisel plow. Hygiene scores were recorded bi-weekly as cows exited the milking parlor. Incidence of clinical mastitis was recorded in a binary manner as treated (1) or not treated (0) during a lactation. Frostbite incidence was collected monthly. Activity and rumination time (daily and 2-h periods) were monitored electronically using HR-LD Tags from SCR Dairy. Indoor cows had greater udder hygiene scores (1.7 vs. 1.5) and greater abdomen hygiene scores (1.9 vs. 1.6) compared with outdoor cows. Incidence of clinical mastitis was greater for indoor cows compared with outdoor cows (29.8% vs. 12.8%, respectively). Frostbite incidence was not different between indoor (34.3%) and outdoor (21.1%) cows. Daily rumination was 477 min/d for indoor cows and 508 min/d for the outdoor cows. In summary, cows housed outdoors on straw-bedded packs had cleaner udders and improved udder health compared with indoor cows.

Key words: activity, rumination, organic

INTRODUCTION

Out wintering continues to increase in popularity for organic dairy producers. Organic dairy farming in the US is based on a pasture production system with intensive rotational grazing during the summer months (USDA-NOP, 2015). However, as cows are transitioned from pasture for the winter months, cows are usually removed from pasture and fed stored feeds harvested from the previous crop season.

Housing systems in in the Upper Midwest of the US, which has cold and snowy winters, include tie-stall barns, free-stall barns, compost barns, and “out-wintering” on bedded packs with wind shelters (Barberg et al., 2007a, 2007b). Dairy producers with compost bedded pack barn have reported improved cow cleanliness, and most were satisfied with the compost bedded pack barn as a housing system for dairy cows (Black et al., 2013). However, housing cows in protected areas or on outdoor packs without a barn has been an effective and low cost housing system for organic dairy producers (Posner, et al. 2009).

Currently, dairy cattle are commonly housed outdoors during the winter months in the Ireland (Boyle et al., 2008, O’Driscoll et al., 2008a, 2008b, 2009, 2010). O’Driscoll et al. (2009) reported production was not compromised for cows housed in outwintering pads during the winter in Ireland. Furthermore, O’Driscoll et al. (2008a; 2008b) found outwintering had little effect on lameness and udder health.

Few studies have been conducted on the comparison of lactating dairy cows housed outdoors compared to cows housed indoors during the winter in the US for hygiene, animal health and well-being, and activity and rumination. Therefore, the objective of this study was to investigate the effect hygiene, clinical mastitis, incidence of frostbite, and activity and rumination of organic dairy cows housed indoors in a compost bedded pack barn or outdoors on a straw pack.

MATERIALS AND METHODS

Experimental Design and Recording of Data

This study was conducted at the University of Minnesota West Central Research and Outreach Center (**WCROC**) Morris, Minnesota, and all animal procedures involving animal care and management were approved by the University of Minnesota Institutional Animal Care and Use Committee. The research dairy at the WCROC has a 250-head low-input and organic grazing system. The research herd has implemented a crossbreeding design since 2000. Details about the breeding program are thoroughly described in Heins et al. (2010).

The study was conducted over 1 winter season (December 2013 to April 2014). During the study, the Midwest US experienced one of the coldest winter seasons on record. The average temperature at the WCROC dairy ranged from -14.4 to 5.0 Celsius (Sjostrom et al., 2015).

Organic Holstein and crossbred dairy cows were divided into replicated groups balanced by parity, breed, and calving date, and assigned to 2 different housing systems. The treatments were an outdoor wintering lot (**OUTDOOR**) bedded with organic wheat straw, or open-front compost bedded pack barn (**INDOOR**) with organic approved sawdust. The lactating cows were introduced to their respective housing systems after the soil was frozen in December, and were removed when pastures were ready for the grazing in late April. Throughout the winter, animals were milked twice a day, and fed a TMR that includes organic corn silage, alfalfa silage, organic dry alfalfa hay, organic expelled soybean meal, organic corn, and vitamins and minerals. Cows were milked in a swing-9 para-bone milking parlor at 06:00 and 17:00.

Data were collected for 82 organic lactating dairy cows and cows calved during fall (September to November) or spring (March to May) seasons: 43 INDOOR cows and 39 OUTDOOR cows during the winter study. Breed groups of cows include pure Holsteins and various crossbreds of Jersey, Holstein, Montbéliarde, Swedish Red, and Normande.

Outdoor straw pack

Two replicated wintering lots (OUTDOOR cows) were established at the WCROC dairy. Each lot was 0.40 hectare in size and contained loafing and feeding areas. An existing coniferous tree line on the north side of the lots served as a windbreak. Each lot had a loafing area bedded with organic wheat straw, 12.2 m wide by 27.4 m long that was maintained as a bedding pack by adding organic wheat straw as needed to keep the cows dry and effectively absorb manure and urine throughout the winter. Bedding was usually added every 2 to 3 d depending on weather conditions. Cows remained in their lots, except for twice daily milking at the nearby (30.5 m) milking parlor.

Compost bedded pack barn

An existing barn at WCROC was divided into 2 independent sections to house the remaining two groups of cows (INDOOR cows). The pack was bedded with organic-approved sawdust. The feeding has 0.76 m of bunk space per cow and is located on a concrete lot outside the compost bedded pack barn. Thereafter, compost beds were turned twice daily to a depth of 18 to 24 cm while the cows were being milked, by a cultivator modified to fit on a skid-steer loader. Fresh bedding was added as needed to keep bedding moisture below 60%, which was every 2 to 3 days.

Hygiene

To evaluate animal hygiene and well-being, all cows in each housing system were visually scored for locomotion, hygiene, and hock lesions bi-weekly during the study. Lameness was scored using a 5-point locomotion scoring method, with 1 = normal locomotion, 2 = imperfect locomotion, 3 = lame, 4 = moderately lame, and 5 = severely lame (Flower and Weary, 2006). Hygiene scores were assessed for udder, flank, belly, lower legs, and upper legs by cleanliness, with 1 = clean to 5 = dirty (Reneau et al., 2005). Hock lesions were classified as 1 = no lesion, 2 = hair loss (mild lesion), and 3 = swollen hock with or without hair loss (severe lesion) (Lobeck et al. 2011). All hygiene and locomotion scoring was performed by one observer as cows were exiting the milking parlor.

For statistical analysis of hygiene, locomotion, and hock lesions, independent variables were effects of parity, housing group, along with cow and replicate as a random effect. For all analyses, the MIXED procedure of SAS (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 $P < 0.05$.

Frostbite and Clinical Mastitis

Incidence of clinical mastitis was recorded in a binary manner as treated (1) or not treated (0) during the winter study. Although organic animals are not allowed to be treated with antibiotics for a mastitis event, cows in this study with a clinical mastitis diagnosis were provided udder mint cream on their udder to reduce swelling and subsequent milk was removed from the bulk tank until the milk was normal.

Frostbite, chapped teats, and teat end scores were recorded 4 times during the study on all 4 quarters of cows. Frostbite and chapped teats were scored: 1=none, 2=frostbite or chapping, 3=severe frostbite or chapping. Teat end scores were 1=no ring, 2=smooth or slightly rough ring, 3=rough ring, 4= very rough ring, and 5 = open lesions or scabs (Mein et al, 2001 and Seiber and Farnsworth, 1981). For statistical analysis, frostbite and chapped teats were recorded in a binary manner as frostbite/chapped (1) or no frostbite/chapped (0) on teats during the study.

For statistical analysis of clinical mastitis frostbite, chapped teats, and teat end scores, independent variables were effects of season of calving, parity, housing systems, along with cow, date, and replicate as a random effect. Additionally, for frostbite, chapped teats, and teat end scores, a variable, front teats versus rear teats, was included in the model. The MIXED procedure of SAS (SAS Institute, 2014) was used to obtain solutions and conduct the ANOVA. The GLIMMIX (SAS Institute, 2014) procedure of SAS was used to determine the statistical significance for clinical mastitis, frostbite, and chapped teats because they were binary traits. All treatment results were reported as least squares means, with significance declared at $P < 0.05$.

Activity and Rumination

All 82 cows were fitted with an HR-LD activity and rumination monitoring collar (SCR Engineers, Netanya, Israel) around the neck (Schirmann, et al., 2009). Due to manufacturer's settings, the ARS collect data for 7 d before calculating a baseline activity and rumination index. The monitors hold 24-hours of data and correspond with a long distance (LD) antenna placed atop the milking center. The antenna had a range of several hundred meters depending on the weather and other environmental factors. Each time the cattle returned to the milking center, and if they were in paddocks nearby the milking center, the antenna would download data as often as every 20 min.

Independent variables for statistical analysis of daily activity, daily rumination, activity at 2-hr intervals, and rumination at 2-hr intervals were effects of month, housing group, interaction of month and housing group. Additionally, replicate was a random effect with measurement date as repeated measures. For activity and rumination at 2-hr intervals, 2-hr time block and the interactions of 2-hr time block and housing group, was added to the model. The autoregressive covariance [AR(1)] structure was used because it resulted in the lowest Akaike's information criterion (Littell et al., 1998). The HPMIXED procedure of SAS (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

Hygiene

Least squares means for hygiene across the winter season for OUTDOOR and INDOOR cows are in Table 1. The INDOOR cows had greater ($P < 0.05$) abdomen hygiene scores (1.86 vs. 1.56) and greater ($P < 0.05$) udder hygiene scores (1.7 vs. 1.5). The INDOOR cows did not differ for cleanliness on the tail head or the lower portion of the rear legs. Although the groups of cows were different for hygiene, the difference did not equate into improved SCS for the OUTDOOR cows, which may be expected based on the study of Reneau et al. (2005) as the difference was small.

For hock scores, INDOOR cows had greater ($P < 0.05$) hock scores (1.1 vs. 1.0) than OUTDOOR cows; however, there may be no biological difference between cow groups for hock scores. Locomotion scores were low for both groups indicating that most cows were walking normally and had excellent feet and leg health. The results for hygiene are contrary to those reported by O'Driscoll et al. (2008a) and Boyle et al. (2008) who found cows housed on outwintering pads had higher dirtiness scores than cows housed indoors. However, in that study in Ireland, cows housed outdoors were bedded with woodchips, and in the current study straw was used. Furthermore, O'Driscoll et al. (2008a) reported no differences in locomotion scores between cows housed indoors or outdoors, which is in agreement with the results of the current study.

Frostbite and Clinical Mastitis

Means for clinical mastitis, frostbite, chapped teats, and teat end scores for INDOOR and OUTDOOR cows are in Table 2. The INDOOR cows had a greater ($P < 0.05$) treatment rate for clinical mastitis (29.8% vs. 12.8%, respectively) compared to OUTDOOR cows. Clinical mastitis may have been greater in INDOOR cows because the compost bedding had greater moisture content than straw bedding. Black et al. (2014) indicated that bacteria that cause mastitis flourish in compost bedded pack barns, which was in agreement with the current study. The mastitis incidence was similar to

Heins et al. (2011) who reported mastitis incidence for conventional dairy cattle of 24.3% to 71.6% in previous experiments with similar climatic conditions in Minnesota.

For incidence of frostbite, the INDOOR (34.3%) cows were not different (P = 0.14) from OUTDOOR (21.1%) cows. The INDOOR cows may have had a greater incidence of frostbite because the INDOOR cows may have been exposed to more windy conditions on very cold days and evenings during the walk from the milking parlor to the barn, which was greater than the walk to the straw packs for the OUTDOOR cows. Furthermore, the frostbite incidence may be of great concern to dairy producers; however, the study was conducted during one of the coldest winters on record in the Upper Midwest. Only 8 cows (9.7% of the total cows and 2.4% of the total teats) experienced a very severe case of frostbite on an individual quarter. All of the cows recovered from frostbite and no teats were totally damaged because of frostbite. The INDOOR cows were not different from the OUTDOOR cows for percentage of chapped teats and teat end scores. During cold weather, all cows were post-dipped with an approved chlorhexidine powder dip that may have caused more chapped teats than expected during the winter because teats were less conditioned than with a liquid post dip.

Activity and Rumination

Least squares means and standard errors for daily activity and rumination across the winter season for winter housing systems of organic dairy cows are in Table 3. For daily activity by month across winter housing groups, cows in April (590) had greater ($P < 0.05$) activity than cows in December (469), January (465), February (492) and March (539). It is not surprise that activity was greater for cows in April, because the weather was much warmer than in December and January and cows were more active. For daily rumination, cows in March (473 min/d) and April (489 min/d) had lower (P < 0.05) rumination than cows in December (503 min/d), January, (490 min/d), and February (509 min/d). Daily activity rose from December and January, through April which had the warmest temperatures in the study. Conversely, rumination decreased during March and April; however, daily rumination was similar for December and February. Cows were consuming more feed during the cold months to maintain body heat, and therefore, had greater daily rumination

For winter housing groups across months, the INDOOR cows had greater (P < 0.05) daily activity (538) compared to the OUTDOOR (484) cows, simply because they had a greater distance to walk to and from the milking parlor compared to the outdoor cows. Conversely, for daily rumination, the INDOOR (477 min/d) cows were lower (P < 0.05) compared to the OUTDOOR (508 min/d) cows. The results from the current study for daily rumination are greater than those reported by Gregorini et al. (2013); however, that study was conducted with grazing dairy cattle during the grazing season. This is the first study to monitor daily and activity in dairy cattle during harsh winter conditions. Although the winter climate in the Upper Midwest may not be appreciated by dairy producers that outwinter cows, the cattle housed outdoors have similar behavior to cattle in confinement.

Figure 1 has means for activity by 2-h intervals and Figure 2 has means for rumination by 2-h interval for OUTDOOR and INDOOR cows. All cows increased in activity from 04:00 to 06:00 h throughout the day until 16:00 h. The OUTDOOR cows had greater activity (P < 0.05) during the early morning and early evening hours because of the movement to the milking parlor and back to the compost bedded pack barn. Activity levels decreased tremendously at 18:00 hours and remained low until 04:00 h.

For rumination across 24 h (Figure 2), the OUTDOOR cows had lower ($P < 0.05$) rumination from 08:00 h to 12:00 h, and from 18:00 to 20:00 h than the INDOOR cows. Surprisingly, numerical differences for rumination between INDOOR and OUTDOOR cows were very similar. All cows had access to the outdoors, so differences in rumination may be negated.

All of the winter housing groups of cows ruminate during the night and remain active during the day (Figure 1 and 2). Nonetheless, the results are similar to Schirmann et al. (2012) who reported cows had greater rumination per hour during the night and early morning compared to the day.

Outwintering of lactating dairy cattle may be generally cleaner, without a decrease in animal well-being and health. In fact, OUTDOOR cows in this study had fewer health problems than INDOOR cows. The current study indicates that outwintering does not decrease welfare for cattle in low-input environments. Investments in buildings are reduced, although some of the economies may be offset by lower milk production and increased energy requirements. A plan to provide for safety of people and animals during the coldest of weather conditions is needed.

CONCLUSIONS

Outwintering of organic lactating dairy cattle in the Upper Midwest is being explored mostly for its potential to improve animal health and well-being and reduce labor costs on farm. The current study found cows housed outdoors had lower hygiene scores, less clinical mastitis, and numerically less frostbite compared to cows housed indoors. Organic dairy producers who can tolerate colder temperatures in the Northern part of the US, may benefit from housing cows outdoors without sacrificing animal health and well-being.

ACKNOWLEDGEMENTS

The authors express gratitude to Darin Huot and coworkers at Morris for their assistance in data collection and care of animals. Financial support was provided for this project by The Ceres Trust (Chicago, IL) and by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2012-51300-20015.

Table 1. Least squares means for hygiene across the winter season for winter housing systems of organic dairy cows.

	Indoor compost-bedded pack		Outdoor straw pack	
Measurement	Mean	SEM	Mean	SEM
Tail head	2.3	0.1	2.3	0.1
Upper leg	2.3	0.1	2.0†	0.1
Lower leg	2.6	0.1	2.5	0.1
Abdomen	1.9	0.1	1.6**	0.1
Udder	1.7	0.1	1.5**	0.1
Hock score	1.0	0.1	1.1**	0.1
Locomotion score	1.1	0.1	1.0	0.1

†$P < 0.10$ for difference from indoor compost bedded-pack
**$P < 0.01$ for difference from indoor compost bedded-pack

Table 2. Least squares means for clinical mastitis and frostbite and teat condition across the winter season for winter housing systems of organic dairy cows.

	Indoor compost-bedded pack		Outdoor straw pack	
Measurement	Mean	SEM	Mean	SEM
Clinical mastitis (%)	29.8	9.1	12.8**	8.9
Frostbite (%)	34.3	14.3	21.1	14.2
Chapped teats (%)	9.2	5.0	8.5	4.6
Teat end score	2.6	0.7	2.2	0.7

**$P < 0.01$ for difference from indoor compost bedded-pack

Table 3. Least squares means and standard errors for daily activity and rumination across the winter season for winter housing systems of organic dairy cows.

	Daily activity		Daily rumination	
	Mean	SE	Mean	SE
	---- (activity units)----		---- (min/d)----	
Month				
December	469[a]	16.9	503[a]	4.7
January	465[a,b]	16.8	490[b]	4.6
February	492[c]	17.0	509[a,c]	4.8
March	539[d]	16.8	473[d]	4.6
April	590[e]	17.2	489[d]	5.3
Housing group				
Indoor compost bedded pack	538[a]	22.5	477[a]	3.1
Outdoor straw pack	484[b]	22.5	508[b]	3.1

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

Figure 1. Activity index of indoor bedded pack and outdoor straw pack organic dairy cows in two-hour increments.

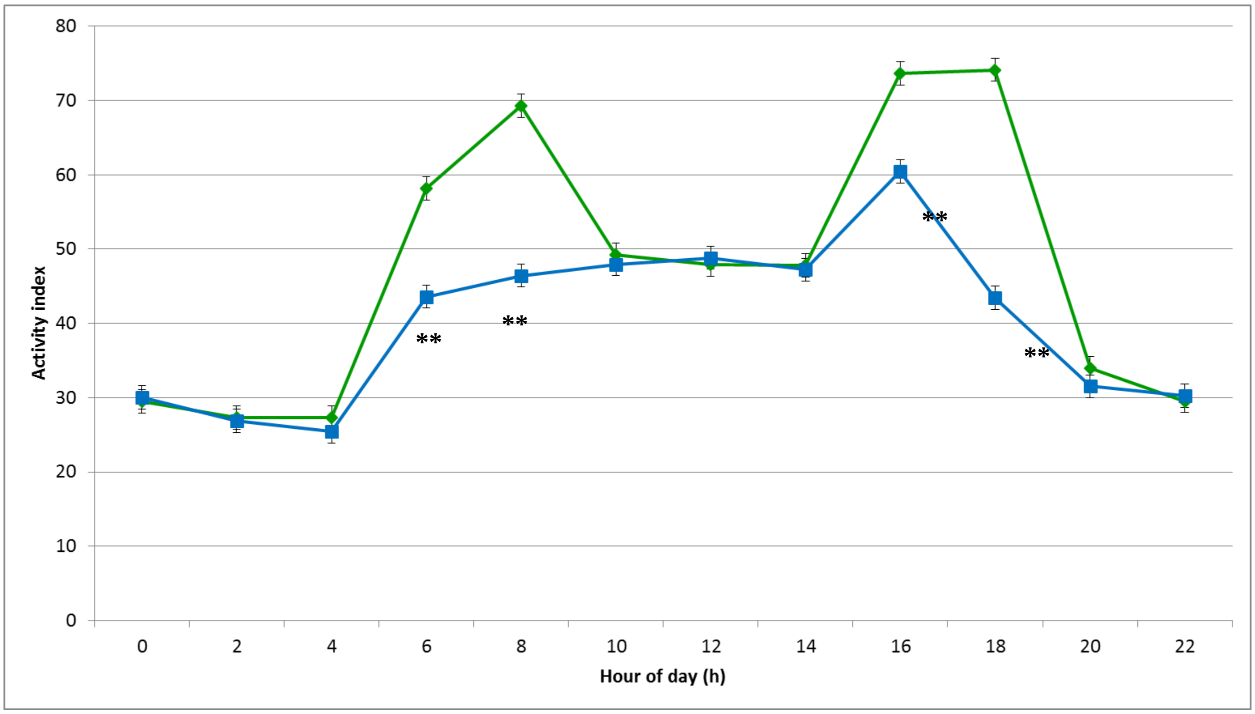

Figure 2. Rumination time of indoor bedded pack and outdoor straw pack organic dairy cows in two-hour increments.

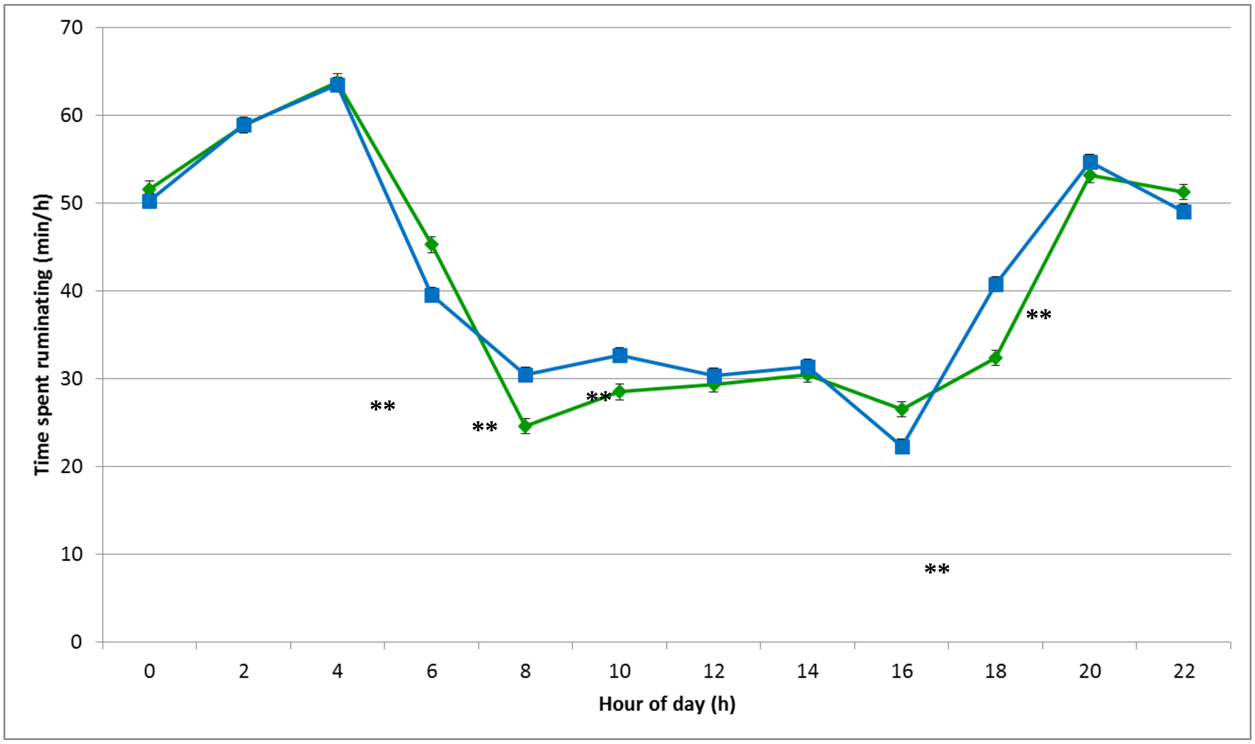

Figure 1. Least squares means for activity index by 2-h intervals for indoor compost bedded pack and outdoor straw pack organic dairy cows (♦ = indoor compost bedded pack cows, ■= outdoor straw pack cows). **$P < 0.01$ for difference from indoor compost bedded-pack

Figure 2. Least squares means for rumination (min.) by 2-h intervals for indoor compost bedded pack and outdoor straw pack organic dairy cows (♦ = indoor compost bedded pack cows, ■= outdoor straw pack cows). **$P < 0.01$ for difference from indoor compost bedded-pack

PRODUCTION, BODY WEIGHT, AND BCS OF OUTWINTERING ORGANIC COWS

Effects of winter housing systems on milk production, body weight, BCS, and bedding cultures of organic dairy cows

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SUMMARY

Certified-organic dairy cows (n = 165) were used to evaluate the effect of two winter (December to April) housing systems on milk production, SCS, body weight, and BCS. Bedding cultures from the housing systems were also evaluated. Cows were assigned to two treatments (two replicates per group): 1) outdoor (straw pack, n = 81) or 2) indoor (3-sided compost-bedded pack barn, n =84). There were 21 cows per replicate per year for the outdoor housing and 21 and 20 cows per replicate per year for the indoor housing. Cows calved during two seasons (spring or fall) at the University of Minnesota West Central Research and Outreach Center, Morris, Minnesota, organic dairy. Organic wheat straw was used as bedding for the 2 outdoor bedded packs, which were 12 m wide by 27 m long, and maintained by farm management to keep cows dry and absorb manure throughout the winter. The open-front compost-bedded pack barn (2 pens in the barn) was bedded with organic approved sawdust, and the bedding material was stirred twice per day with a small chisel plow. Cows were fed a TMR that included organic corn silage, alfalfa silage, corn, expelled soybean meal, vitamins and minerals. Milk, fat and protein production and SCS were recorded from monthly DHIA testing. Body weight and BCS were recorded bi-weekly as cows exited the milking parlor. The PROC MIXED of SAS was used for statistical analysis, and independent variables were fixed effects of year, season of calving, parity, housing system, with replicate and cow as a random effect. Energy-corrected milk and SCS was not different for the outdoor (15.3 kg/d, 2.88) and indoor (15.9 kg/d, 2.75) housing systems, respectively. In addition, outdoor and indoor housing systems were not different for body weight (537 vs. 542 kg) and BCS (3.25 vs. 3.28), respectively. Daily DMI was not different between INDOOR and

OUTDOOR groups, at 19 kg/day. The total bacteria count tended to be lower in the outdoor (13.0 $_{log10}$ CFU/ml) compared to the indoor (14.9 l $_{log10}$ CFU/ml) system. In summary, cows housed outdoors on straw-bedded packs did not differ from cows housed in an indoor compost-bedded pack barn for production and SCS, as well as body weight, BCS, or DMI.

Key words: organic, outwintering, compost barn

INTRODUCTION

Dairy producers from the United States, especially from the Upper Midwest, have turned to an organic production system to capitalize from the higher milk price received for organic milk. The number of organic dairy farms has increased during the past decade (McBride and Greene, 2009), slowing the decline of smaller dairy operations in the Upper Midwest. The number of certified organic dairy cows in the United States has increased tremendously, and Minnesota had over 10,000 certified organic dairy cows in 2011 (USDA, 2012). The number of organic dairy farms has increased due to the fact that in 2002, the United States Department of Agriculture introduced the National Organic Program (**NOP**) as a method of standardization for organic agriculture (USDA National Organic Program, 2015).

The NOP standards became effective in 2002 and address production, certification, recordkeeping, and inputs allowed in organic farming (USDA-NOP, 2015). Pasture and land for production of organic crops must not have had any prohibited substances, such as synthetic fertilizers or pesticides, applied to it 3 yr before the first use of the crop for organic purposes (USDA-NOP, 2015). All certified organic livestock must be fed organic feed from certified organic land. Growth hormones and antibiotics are not allowed to be provided to livestock in organic production systems (Stiglbauer et al., 2013). However, it is forbidden to withhold medical treatment from a sick animal to keep its organic status (USDA-NOP, 2015).

The USDA-NOP also dictates that organic livestock must maintain living conditions that accommodate the natural behavior of animals. The rules also state that animals must have year-round access to the outdoors, shelter, exercise areas, fresh air, and direct sunlight, and continuous confinement is prohibited (USDA-NOP, 2015).

Currently, an increasing number of organic dairy producers are choosing to explore outwintering options for heifers and cows. Low cost of production is very important to smaller dairy herds. Quest for profitability and increased public interest in farm animal welfare have fostered a need to investigate winter housing options for organic dairy cattle. Dairy cattle are commonly housed outdoors during the winter months in Ireland (Boyle et al., 2008).

Out-wintering systems in Ireland were found to be a suitable wintering option for beef cattle and cows had greater ADG than cows housed indoors (Hickey, et al., 2002). O'Driscoll et al. (2008) reported SCS during the following lactation was not affected by housing dry dairy cows outdoors. Furthermore, O'Driscoll et al. (2010) found milk, fat, and protein production was similar for cows housed outdoors versus indoors. In Sweden, Redbo et al. (2001) showed dairy heifers can be housed outdoors if they are provided a wind break and a clean and dry place to lie down.

Housing options in Minnesota, which has much colder winters, include tie-stall barns, free-stall barns, compost barns, and "out-wintering" on bedded packs with wind shelters (Barberg et al., 2007a). Beef cows and older dairy heifers can thrive with minimal shelter during Minnesota winters (MDA, 2008). In contrast, milk cows have generally been kept indoors, in part because they were milked in tie-stall barns. More recently, free stall barns have become the standard housing of larger confinement herds (Zwald et al., 2004). However, compost bedded pack barns have been used as housing for dairy herds (Barberg et al., 2007b). Dairy producers with compost bedded pack barns have reported improved cow cleanliness, and most were satisfied with the compost bedded pack barn as a housing system for dairy cows (Black et al., 2013).

Few studies have been performed comparing lactating dairy cows housed outdoors with cows housed indoors during the winter in the US. Therefore, the objective of this study was to investigate the effect of two wintering systems on BW, BCS, DMI, production, SCS, and bacterial pathogens in bedding cultures of organic dairy cows housed indoors in a compost bedded pack barn or outdoors on a straw pack.

MATERIALS AND METHODS

Experimental Design and Recording of Data

This study was conducted at the University of Minnesota West Central Research and Outreach Center (**WCROC**) Morris, Minnesota, and all animal procedures involving animal care and management were approved by the University of Minnesota Institutional Animal Care and Use Committee. The research dairy at the WCROC has a 250-head low-input and organic grazing system. The research herd has implemented a crossbreeding design since 2000. Details about the breeding program are thoroughly described in Heins et al. (2010).

The study was conducted over 2 winter seasons (December 2012 to April 2013 and December 2013 to April 2014). During the first year of the study (2012-2013) the average monthly temperature were near normal averages; however, an enormous amount of snowfall (137.7 cm) was recorded during that particular winter compared to historical averages (Table 1). Conversely, during the second year of the study (2013-2014), the US experienced one of the coldest winter seasons on record. The average temperature at the WCROC dairy ranged from -14.4 to 5.0 Celsius and snowfall was only 59.1 cm, and most snow occurred during December 2013 (Table 1).

Organic Holstein and crossbred dairy cows were divided into replicated groups balanced by parity, breed, and calving date, and assigned to 2 different housing systems. The treatments were an outdoor wintering lot (**OUTDOOR**) bedded with organic wheat straw, or open-front compost bedded pack barn (**INDOOR**) with organic approved sawdust. The lactating cows were introduced to their respective housing systems after the soil was frozen in December, and were removed when pastures were ready for the grazing in late April. Throughout the winter, animals were milked twice a day, and fed a TMR that includes organic corn silage, alfalfa silage, organic dry alfalfa hay, organic expelled soybean meal, organic corn, and vitamins and minerals. The ration comprised 13.7% CP, 36.7% NDF, 3.1% fat, 1.13% calcium, 0.36% phosphorus, 35.9% NFC, 65.7 Mcal/cwt NE_L, and 68.9 Mcal/cwt NE_M.

Data were collected for 165 organic lactating dairy cows from 2 study years, and cows calved during fall (September to November) or spring (March to May) seasons: 41 INDOOR cows and 42 OUTDOOR cows during the first year of the study (2012-2013), and 43 INDOOR and 39 OUTDOOR cows during the second year (2013-2014) of the study. Breed groups of cows include pure Holsteins and various crossbreds of Jersey, Holstein, Montbéliarde, Swedish Red, and Normande. Breed groups of cows were:

Holsteins (n = 43) maintained at 1964 breed average level, Holstein-sired crossbreds (N = 40), Jersey-sired crossbreds (n = 49), and Viking Red (Swedish Red) crossbreds (n = 33). The distribution of cows by breed group and housing group is presented in Table 1.

Outdoor straw pack

Two replicated wintering lots (OUTDOOR cows) were established at the WCROC dairy. Each lot was 0.40 hectare in size and contained loafing and feeding areas. An existing coniferous tree line on the north side of the lots served as a windbreak. Each lot had a loafing area bedded with organic wheat straw, 12.2 m wide by 27.4 m long that was maintained as a bedding pack by adding organic wheat straw as needed to keep the cows dry and effectively absorb manure and urine throughout the winter. Bedding was usually added every 2 to 3 d depending on weather conditions. Cows remained in their lots, except for twice daily milking at the nearby (30.5 m) milking parlor.

Compost bedded pack barn

An existing barn at WCROC was divided into 2 independent sections to house the remaining two groups of cows (INDOOR). The pack was bedded with organic-approved sawdust. Cows had 0.76 m of feed bunk space located on a concrete lot outside the compost bedded pack barn. Initially, 0.45 to 0.61 m of organic-approved sawdust bedding material was added to each replicated section. Thereafter, compost beds were turned twice daily to a depth of 18 to 24 cm while the cows were being milked, by a cultivator modified to fit on a skid-steer loader. Fresh bedding was added as needed to keep bedding moisture below 60%, which was every 2 to 3 days. During the month of February of each year, about one-half of the bedding material was removed from the pack area because the compost barn was not able to be tilled because the height of the barn prevented the skid loader from entering the pack.

Daily feed consumption by each replicated group was monitored as the difference between feed offered and refused, using a TMR feeding wagon equipped with Feed Supervisor herd management software (Supervisor Systems, KS Dairy Consulting, Inc., Dresser, WI). Milk production was quantified with monthly DHI measures of milk, fat, protein, SCC, and milk urea nitrogen. To evaluate animal health, cow BW and BCS were recorded bi-weekly using a digital scale as cows exit the milking parlor in the morning. Body condition scores were 1 = excessively thin to 5 = excessively fat (Wildman et al., 1982).

Analysis of bedding material

Bedding samples were collected for bacterial analysis. A composite of 5 samples was collected from the top 5 centimeters of both the straw pack (OUTDOOR system) and composted bedded pack barn (INDOOR system). In both cases, samples were collected by dividing the area into five sections, four outside corners and one in the middle, then taking the sample not within two feet of a wall or the outside of the pack. Samples were taken during morning milking, to replicate what the cows would return to after milking. The bedding samples were immediately frozen until analysis by the Laboratory for Udder Health, University of Minnesota College of Veterinary Medicine, St. Paul, MN.

Statistical Analysis

For statistical analysis of BW and BCS, independent variables were effects of year of study (2013 or 2014), season of calving (spring or fall) nested with year of study, parity nested within year of study, housing system (INDOOR or OUTDOOR), housing system nested with year of study, 14-d period nested with housing system, along with cow and replicate as a random effect. The autoregressive covariance [CS] structure was used because it resulted in the lowest Akaike's information criterion (Littell et al., 1998).

For statistical analysis of DMI, milk, fat, and protein production, ECM, SCS, and MUN, independent variables were effects of DIM as a covariate, year of study, parity nested within year of study, housing systems, housing system nested with year of study, and cow and replicate as a random effects. Additionally, for daily DMI, date was included as a random effect as repeated measures.

For bacterial analysis of bedding material, all data were log transformed to adjust for lack of normality. For statistical analysis of bacterial pathogens in clean and soiled bedding, independent variables were effects of year of study and housing system, along with date and replicate as a random effect. For all analyses, The MIXED procedure of SAS (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

Body Weight and BCS

Table 3 reviews the BW and BCS across both years of the study for INDOOR and OUTDOOR cows. For BW, the INDOOR (542 kg) cows were not different compared to the OUTDOOR (537 kg) cows. The INDOOR (539 kg; 545 kg) cows and OUTDOOR (528 kg; 547 kg) were not different for BW for both years (2012-2013, 2013-2014), respectively. Across the winter season, BW ranged 528 to 563 kg for INDOOR cows and 525 to 559 kg for OUTDOOR cows.

For BCS, the INDOOR (3.28) cows were not different compared to the OUTDOOR (3.25) cows. The BCS was not different for both housing group of cows for each year. Across the season, BCS ranged 3.13 to 3.33 for INDOOR cows and 3.21 to 3.30 for OUTDOOR cows. Results for BCS across the winter season were consistent with the results of O'Driscoll et al. (2010), who also reported that INDOOR cows and OUTDOOR cows had similar BCS. Tucker et al. (2007) found dairy cows housed indoor versus outdoor during the winter in California had similar BCS. Furthermore, Tucker et al. (2007) reported that cows with greater BCS may mitigate the effects of cold, harsh winter weather on cows. The higher BCS of cows in this study compared to other studies (Washburn et al., 2002) may have lessened the effects of winter weather on the organic cows.

DMI and Milk Production

Least squares means and standard errors for DMI, milk production, SCS, and MUN across the winter season and year for housing system are in Table 4. The INDOOR (19.1 kg/d) cows were not different compared to the OUTDOOR (18.8 kg/d) for DMI. The expectation was that the OUTDOOR cows would consume more DMI intake because the cows were outside exposed to harsher environmental conditions; however, this was not observed in this study. That being said, the cows we are labeling as INDOOR had a barn open to the elements on one of four sides. Previous studies have reported cows will spend more time eating in response to cold environmental conditions (Redbo et al., 2001). Typically, thinner cows consume more DMI than cows with greater BCS (Tucker, et al., 2007); however, BCS was not different in this study, and this may be a reason why DMI did not differ. All groups of cows consumed about 20% more DMI in the second year of the study because the ambient air temperature and wind chill was much lower compared to the first year (Table 1). Despite the notion that cows in colder environments should consume more DMI, results of the current study are similar to Hickey et al. (2002) and O'Driscoll et al. (2009) who reported similar DMI for cows indoors versus cows housed in outdoor wintering pads.

The INDOOR cows were not different (P > 0.05) from OUTDOOR cows for any measure of production. The INDOOR and OUTDOOR cows were not different for ECM (15.5 kg/d vs. 15.3 kg/d, respectively). The SCS was similar (2.75 vs. 2.88) for the INDOOR and OUTDOOR cows. O'Driscoll et al. (2008) reported that cows housed outdoors had similar SCS compared to cows housed indoors, which is in agreement with the current study. The MUN (6.3 mg/dL vs. 6.5 mg/dL) was not different between housing groups. The production results are similar to O'Driscoll et al. (2010) who reported cows housed in sheltered outwintering pads had similar fat and protein production compared to cows housed inside a barn. Possibly, production results may be different if the average production level of cows was much higher than observed in this study. Organic cows in this study were fed a lower protein ration than found in confinement herds simply because the high cost of organic protein supplements and organic corn does not economically justify feeding for maximum milk production.

Bedding cultures

Least squares means for bacterial pathogens in clean and soiled bedding material across the winter season and year for winter housing systems of organic dairy cows are in Table 5. The clean straw bedding samples had greater ($P < 0.01$) numbers of bacillus (10.4 $\log_{10}$ CFU/ml vs. 7.5 $\log_{10}$ CFU/ml), staph species (5.4 $\log_{10}$ CFU/ml vs. 0.0 $\log_{10}$

CFU/ml), and total bacterial load (10.5 $\log_{10}$ CFU/ml vs. 7.6 $\log_{10}$ CFU/ml) compared to clean sawdust bedding. It was expected that the clean sawdust bedding would have lower bacterial pathogens because the sawdust was dried prior to delivery at WCROC dairy and it doesn't include soil with it. The wheat straw could have already contained pathogens from the environment from where it was harvested or transported.

Conversely, the soiled bedding samples found the opposite results as the clean bedding samples. The straw bedding samples tended ($P < 0.10$) to have fewer bacillus (12.1 $\log_{10}$ CFU/ml vs. 14.4 $\log_{10}$ CFU/ml) and fewer ($P < 0.05$) coliforms (6.5 $\log_{10}$ CFU/ml vs. 11.9 $\log_{10}$ CFU/ml) and tended ($P < 0.10$) to have fewer total bacteria (13.0 $\log_{10}$ CFU/ml vs. 14.9 $\log_{10}$ CFU/ml) compared to soiled sawdust bedding samples from the compost bedded pack barn. Sawdust and straw bedding samples were not different for environmental strep.

The results for bacterial species load in the compost barn are greater than the results reported by Black et al. (2014), Shane et al. (2010) and Barberg et al. (2007a). However, Black et al. (2014) reported on herds in Kentucky, which had very different climatic conditions during the winter than Minnesota. Source of bedding may have contributed to the higher bacterial loads found in the sawdust bedding. The clean sawdust had 7.6 $\log_{10}$ CFU/ml, which was higher than the average soiled bedding samples reported by Barberg et al. (2007a). The high bacteria species found in both the indoor compost bedded pack barn and outdoor straw pack emphasize the importance of superior teat cleaning procedures at the time of milking.

There are several obvious benefits to out-wintering; building costs are lower, diseases associated with close confinement and poor ventilation may be avoided, animals may be generally cleaner, bedding costs could be reduced, feeding may be simplified, and herd size may be adjusted if weather conditions change quickly. Economically, animals in colder climates may require about 10 to 30% more feed for the season compared to animals kept in a confinement free-stall barn housing system, so improvements in animal health and welfare from out-wintering will need to exceed increased feed costs if outwintering is to be a profitable option.

CONCLUSIONS

Outwintering of organic and grazing dairy cattle in the Upper Midwest is being explored mostly for its potential to lower capital costs and reduce labor costs on farm. The current study found cows housed outdoors had similar DMI, production, BW, and BCS compared to cows housed indoors. A colder environment may provide advantages in keeping bedding bacterial pathogens lower in outdoor straw packs compared to bedding in confinement systems. Organic dairy producers who can tolerate colder temperatures in the Northern part of the US, may benefit from housing cows outdoors to reduce farm expenses, without sacrificing production and animal health and well-being.

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Table 1. Mean, high, and low temperature and total snowfall for winter months during 2013 and 2014 at the West Central Research and Outreach Center, Morris, MN organic dairy.

Year	2012-2013					2013-2014				
Variable	December	January	February	March	April	December	January	February	March	April
Average temperature	-8.3	-11.1	-10	-6.7	1.7	-13.9	-14.4	-14.4	-3.9	5.0
Average high temperature	11.7	2.8	1.1	6.1	25.0	3.9	4.4	3.3	15.0	25.5
Average low temperature	-23.3	-26.1	-28.3	-20.0	-10.6	-28.9	-31.1	-26.7	-26.1	-10.6
Total snowfall (cm)	27.2	8.9	48.8	19.8	33.0	26.4	7.9	9.1	15.7	0.0

Table 2. Distribution of organic dairy cows by breed group and winter housing group across the two years.

Breed group	Indoor compost-bedded pack (n)	Outdoor straw pack (n)
1964 Holstein	22	21
Holstein-sired crossbreds	20	20
Jersey-sired crossbreds	26	23
Viking Red-sired crossbreds	16	17
Total cows	84	81

Table 3. Least squares means for BW and BCS across the winter season and year for winter housing systems of organic dairy cows.

	Indoor compost-bedded pack		Outdoor straw pack	
Measurement	Mean	SEM	Mean	SEM
Body weight (kg)	542	8.0	537	8.0
Body condition score	3.28	0.04	3.25	0.03

No significant difference between housing groups for BW or BCS.

Table 4. Least squares means for DMI and production across the winter season and year for winter housing systems of organic dairy cows.

	Indoor compost-bedded pack		Outdoor straw pack	
Measurement	Mean	SEM	Mean	SEM
As-fed intake (kg/d)	40.9	0.5	40.2	0.5
Dry matter intake (kg/d)	19.1	0.3	18.8	0.3
Milk (kg/d)	15.9	1.0	15.3	1.0
Fat (kg/d)	0.62	0.04	0.63	0.04
Fat percent (%)	4.0	0.2	4.2	0.2
Protein (kg/d)	0.53	0.03	0.52	0.03
Protein percent (%)	3.4	0.1	3.5	0.1
Energy corrected milk (kg/d)	15.5	0.6	15.3	0.6
Somatic cell score	2.75	0.15	2.88	0.14
Milk-urea nitrogen (mg/dL)	6.3	0.4	6.5	0.3

No significant difference between housing groups for DMI or production.

Table 5. Least squares means for bacterial pathogens in clean and soiled bedding material across the winter season and year for winter housing systems of organic dairy cows.

Variable	Clean bedding samples				Soiled bedding samples			
	Indoor Compost bedded pack		Outdoor Straw pack		Indoor Compost bedded pack		Outdoor Straw pack	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Bacillus	7.5	0.7	10.4**	0.7	14.4	0.6	12.1†	0.5
Coliforms	4.6	0.9	6.8	2.1	11.8	0.6	6.5*	0.8
Environmental Strep	9.0	2.2	7.6	0.9	13.2	0.6	11.5	0.6
Staph species	0	0.0	5.4**	0.9	6.1	3.8	8.5	1.1
Total bacteria	7.6	0.7	10.5**	0.7	14.9	0.5	13.0†	0.5

†$P < 0.10$ for difference from indoor compost bedded-pack
*$P < 0.05$ for difference from indoor compost bedded-pack
**$P < 0.01$ for difference from indoor compost bedded-pack

REFERENCES

Barberg, A.E., M.I. Endres, and K.A. Janni. 2007b. Dairy compost barns in Minnesota: a descriptive study. Appl. Eng. Agric. 23:231-238.

Barberg, A.E., M.I. Endres, J.A. Salfer, and J.K. Reneau. 2007a. Performance and Welfare of Dairy Cows in an Alternative Housing System in Minnesota. *Journal of Dairy Science*. 90:1575–1583. doi:10.3168/jds.S0022-0302(07)71643-0.

Black, R.A., J.L. Taraba, G.B. Day, F.A. Damasceno, and J.M. Bewley. 2013. Compost bedded pack dairy barn management, performance, and producer satisfaction. *Journal of Dairy Science*. 96:8060–8074. doi:10.3168/jds.2013-6778.

Black, R.A., J.L. Taraba, G.B. Day, F.A. Damasceno, M.C. Newman, K.A. Akers, C.L. Wood, K.J. McQuerry, and J.M. Bewley. 2014. The relationship between compost bedded pack performance, management, and bacterial counts. *Journal of Dairy Science*. 97:2669–2679. doi:10.3168/jds.2013-6779.

Boland, H.T., G. Scaglia, and K. Umemura. 2008. Case Study: Impact of Horn Flies, Haematobia irritans (L.) (Diptera: Muscidae), on the Behavior of Beef Steers. *Professional Animal Scientist*. 24:656–660.

Borchers, M.R., and J.M. Bewley. 2014. An assessment of producer precision dairy farming technology use, prepurchase considerations, and usefulness. J. Dairy Sci. 0. doi:10.3168/jds.2014-8963.

Boyle, L.A., R.M. Boyle, and P. French. 2008. Welfare and performance of yearling dairy heifers out-wintered on a wood-chip pad or housed indoors on two levels of nutrition. *Animal*. 2:769–778. doi:10.1017/S1751731108001870.

Denning, S.S., S.P. Washburn, and D.W. Watson. 2014. Development of a novel walk-through fly trap for the control of horn flies and other pests on pastured dairy cows. J. Dairy Sci. 97:4624–4631. doi:10.3168/jds.2013-7872.

Elischer, M.F., M.E. Arceo, E.L. Karcher, and J.M. Siegford. 2013. Validating the accuracy of activity and rumination monitor data from dairy cows housed in a pasture-based automatic milking system. J. Dairy Sci. 96:6412–6422. doi:10.3168/jds.2013-6790.

Endres, M.I., and A.E. Barberg. 2007. Behavior of Dairy Cows in an Alternative Bedded-Pack Housing System. *Journal of Dairy Science*. 90:4192–4200. doi:10.3168/jds.2006-751.

Flower, F. C. and D. M. Weary. 2006. Effect of hoof pathologies on subjective assessments of dairy cow gait. J. Dairy Sci. 89:139-146.

French, P., K.O. Driscoll, B. Horan, and L. Shalloo. 2015. The economic, environmental and welfare implications of alternative systems of accommodating dairy cows during the winter months. *Anim. Prod. Sci.* 55:838–842.

Gregorini, P., B. Dela Rue, M. Pourau, C. Glassey, and J. Jago. 2013. A note on rumination behavior of dairy cows under intensive grazing systems. Livestock Science. 158:151–156. doi:10.1016/j.livsci.2013.10.012.

Gregorini, P., B. DelaRue, K. McLeod, C.E.F. Clark, C.B. Glassey, and J. Jago. 2012. Rumination behavior of grazing dairy cows in response to restricted time at pasture. Livestock Science. 146:95–98. doi:10.1016/j.livsci.2012.02.020.

Hart, B.L. 1994. Behavioural defense against parasites: interaction with parasite invasiveness. *Parasitology*. 109:S139–S151. doi:10.1017/S0031182000085140.

Heins, B.J., Hansen, L.B., Hazel, A.R., Seykora, A.J., Johnson, D.G., and Linn, J.G. Birth traits of pure Holstein calves versus Montbéliarde-sired crossbred calves. *J. Dairy*

Sci. 2010; 93: 2293–2299

Heins, B.J., L.B. Hansen, A.J. Seykora, A.R. Hazel, D.G. Johnson, and J.G. Linn. 2011. Short communication: Jersey × Holstein crossbreds compared with pure Holsteins for production, mastitis, and body measurements during the first 3 lactations. *Journal of Dairy Science*. 94:501–506. doi:10.3168/jds.2010-3232.

Hickey MC, French P and Grant J 2002. Out-wintering pads for finishing beef cattle: animal production and welfare. Animal Science 75, 447–458.

Kamphuis, C., B. DelaRue, C.R. Burke, and J. Jago. 2012. Field evaluation of 2 collar-mounted activity meters for detecting cows in estrus on a large pasture-grazed dairy farm. J. Dairy Sci. 95:3045–3056. doi:10.3168/jds.2011-4934.

Littell, R.C., Henry, P.R., and Ammerman, C.B. Statistical analysis of repeated measures data using SAS procedures. J. Anim. Sci. 1998; 76: 1216–1231

Lobeck, K.M., M.I. Endres, E.M. Shane, S.M. Godden, and J. Fetrow. 2011. Animal welfare in cross-ventilated, compost-bedded pack, and naturally ventilated dairy barns in the upper Midwest. *Journal of Dairy Science*. 94:5469–5479. doi:10.3168/jds.2011-4363.

Mays, A.R., M.A. Brown, D.L. von Tunglen, and C.F. Rosenkrans. 2014. Milk production traits of beef cows as affected by horn fly count and sire breed type. J. Anim. Sci. 92:1208–1212. doi:10.2527/jas.2013-7147.

McBride, W. D., and C. Greene. 2009. Characteristics, costs, and issues for organic dairy farming. ERR-82, Economic Research Service, US Department of Agriculture, Washington, DC.

McCarrick, R.B., and M.J. Drennan. 1972. Effect of winter environment on growth of young beef cattle 1. Effects of exposure during winter to rain or wind and rain combined on performance of 9-month-old Friesian steers fed on two planes of nutrition. *Animal Science*. 14:97–105. doi:10.1017/S0003356100000313.

Mein, G.A., F. Neijenhuis, W.F. Morgan, D.J. Reinemann, J.E. Hillerton, J.R. Baines, I. Ohnstad, M.D. Rasmussen, L. Timms, J.S. Britt, R. Farnsworth, and N.B. Cook. 2001. Evaluation of bovine teat condition in commercial dairy herds: 1. Non-infectious factors. Proc., 2nd International Symposium on Mastitis and Milk Quality.

Minnesota Department of Agriculture. 1997. Managing winter feeding areas for beef cattle in Minnesota. http://www.mnbeef.umn.edu/cow-calf/2008/e4-managing_winter_feeding_areas.pdf Accessed March 1, 2015

O'Driscoll, K., A. Hanlon, and L. Boyle. 2008c. The Effect of Out-Wintering Pad Design on the Synchrony of Dairy Cow Behavior. *Journal of Dairy Science*. 91:4651–4660. doi:10.3168/jds.2007-0741.

O'Driscoll, K., L. Boyle, A. Hanlon, F. Buckley, and P. French. 2010. The effect of dry cow winter management system on feed intake, performance and estimated energy demand. *Animal*. 4:272–281. doi:10.1017/S1751731109991005.

O'Driscoll, K., L. Boyle, and A. Hanlon. 2009a. The effect of breed and housing system on dairy cow feeding and lying behaviour. *Applied Animal Behaviour Science*. 116:156–162. doi:10.1016/j.applanim.2008.08.003.

O'Driscoll, K., L. Boyle, P. French, and A. Hanlon. 2008a. The Effect of Out-Wintering Pad Design on Hoof Health and Locomotion Score of Dairy Cows. *Journal of Dairy Science*. 91:544–553. doi:10.3168/jds.2007-0667.

O'Driscoll, K., L. Boyle, P. French, B. Meaney, and A. Hanlon. 2008b. The effect of out-wintering pad design on dirtiness score, somatic cell score and mastitis incidence in dairy cows. *Animal*. 2:912–920. doi:10.1017/S1751731108001882.

O'Driscoll, K.K., A. Hanlon, P. French, and L.A. Boyle. 2009b. The effects of two out-wintering pad systems compared with free-stalls on dairy cow hoof and limb health. *Journal of Dairy Research*. 76:59–65. doi:10.1017/S0022029908003695.

Posner, J.L., G.G. Frank, K.V. Nordlund, and R.T. Schuler. 2009. A constant goal, changing tactics: The Krusenbaum dairy farm (1996–2005). *Renewable Agriculture and Food Systems*. 24:8–18. doi:10.1017/S1742170508002378.

Redbo I, Ehrlemark A and Redbo-Torstensson P 2001. Behavioural responses to climatic demands of dairy heifers housed outdoors. Canadian Journal Anim.Sci. 91, 9–15.

Reneau, J.K., A.J. Seykora, B.J. Heins, M.I. Endres, R.J. Farnsworth, and R. F. Bey. 2005. Association between hygiene scores and somatic cell scores in dairy cattle. *Journal of the American Veterinary Medical Association*. 227:1297–1301. doi:10.2460/javma.2005.227.1297.

SAS Institute. 2014. SAS/STAT Software. Release 9.4. SAS Institute Inc., Cary, NC.

Schirmann, K., M. a. G. von Keyserlingk, D.M. Weary, D.M. Veira, and W. Heuwieser. 2009. Technical note: Validation of a system for monitoring rumination in dairy cows. J. Dairy Sci. 92:6052–6055. doi:10.3168/jds.2009-2361.

Schirmann, K., N. Chapinal, D.M. Weary, W. Heuwieser, and M. a. G. von Keyserlingk. 2012. Rumination and its relationship to feeding and lying behavior in Holstein dairy cows. J. Dairy Sci. 95:3212–3217. doi:10.3168/jds.2011-4741.

Seiber, R.L. and R.J. Farnsworth. 1981. Prevalence of chronic teat end lesions and their relationship to intramammary infections in 22 herds of dairy cattle. J. Am. Med. Assoc. 178:1263-1267.

Sorge, U.S., R.D. Moon, B.E. Stromberg, S.L. Schroth, L. Michels, L.J. Wolff, D.F. Kelton, and B.J. Heins. 2015. Parasites and parasite management practices of organic and conventional dairy herds in Minnesota. J. Dairy Sci. 98:3143–3151. doi:10.3168/jds.2014-9031.

Taylor, D.B., R.D. Moon, and D.R. Mark. 2012. Economic Impact of Stable Flies (Diptera: Muscidae) on Dairy and Beef Cattle Production. J. of Med. Ent. 49:198–209. doi:10.1603/ME10050.

Tucker, C.B., A.R. Rogers, G.A. Verkerk, P.E. Kendall, J.R. Webster, and L.R. Matthews. 2007. Effects of shelter and body condition on the behaviour and physiology of dairy cattle in winter. *Applied Animal Behaviour Science*. 105:1–13. doi:10.1016/j.applanim.2006.06.009.

United States Department of Agriculture. 2012. 2011 Certified organic production survey. National Agriculture Statistics Service, October 2012. Accessed Aug., 8, 2015.

USDA-NOP (National Organic Program). 2015. The Program Handbook: Guidance and Instructions for Accredited Certifying Agents and Certified Operations. Accessed Feb. 25, 2015. http://www.ams.usda.gov/about-ams/programs-offices/national-organic-program

Washburn, S. P., S. L. White, J. T. Green Jr, and G. A. Benson. 2002. Reproduction, mastitis, and body condition of seasonally calved Holstein and Jersey cows in confinement or pasture systems. J. Dairy Sci. 85:105–111.

Watson, D.W., S.M. Stringham, S.S. Denning, S.P. Washburn, M.H. Poore, and A. Meier. 2002. Managing the Horn Fly (Diptera: Muscidae) Using an Electric Walk-Through Fly Trap. *Journal of Economic Entomology*. 95:1113–1118. doi:10.1603/0022-0493-95.5.1113.

Wildman, E. E., G. M. Jones, P. E. Wagner, R. L. Boman, H. F. Troutt Jr, and T. N. Lesch. 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics. J. Dairy Sci. 65:495–501.

Zwald, A.G., P.L. Ruegg, J.B. Kaneene, L.D. Warnick, S.J. Wells, C. Fossler, and L.W. Halbert. 2004. Management Practices and Reported Antimicrobial Usage on Conventional and Organic Dairy Farms1. *Journal of Dairy Science*. 87:191–201. doi:10.3168/jds.S0022-0302(04)73158-6.