

Full Length Research Paper

Performance and welfare of dairy cattle in an alternative compost bedded pack housing in a pasture-based system

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The objective of this study was to assess the performance and welfare (lameness, hock lesions, mastitis) of loose-housed dairy cattle managed under grazing or semi-grazing system. Data of thirty-two cows before and after changing to semi-grazing system during the rainy season (week 1 to 4; grazing, week 6 to 9; semi-grazing) and before and after changing to semi-grazing (week 11 to 16; grazing, week 18 to 23, semi-grazing) during the dry season were examined. Cows were evaluated weekly for 24 weeks for somatic cell count (SCC), lameness, hock lesions, and hygiene. Milk yield was collected daily. Bacteria cultures were prepared to identify pathogens. Isolates were subjected to sensitivity tests. No difference was observed between grazing and semi-grazing, regarding milk yield, lameness, hock lesions, SCC, and sub-clinical mastitis prevalence. Mean SCC under grazing was >600,000 cells/ml, indicating infection with major pathogens (*Streptococcus agalactiae*, *Streptococcus dysgalactiae*). *Klebsiella* species increased with season and were less sensitive to common antibiotics. Contagious pathogens in milk were lower (14%) compared with environmental pathogens (82%). Because *Klebsiella* species were less sensitive to many antibiotics, keeping cows healthy is critical. Focus on reducing somatic cell count will be important in preventing mastitis infection in dairy cows.

Key words: Grazing, semi-grazing system, performance, cattle welfare.

INTRODUCTION

Compost bedded pack (CBP) housing is a newer loose housing system designed to provide a large open area containing a bedded pack on which animals can rest (Biasato et al., 2019; Leso et al., 2020). The pack in the CBP is a bed of organic matter actively going through aerobic decomposition in an attempt to keep the surface clean and dry (Black et al., 2014). The dry surface is necessary to reduce teat-end exposure and prevent dirty

cows (Black et al., 2014; Eckelkamp et al., 2016; Biasato et al., 2019). The CBP can be a primary housing structure for lactating cows, for multiple groups of cows, and for special needs cows (Costa et al., 2018; Leso et al., 2020).

The perceived benefits of a CBP include low investment costs, decreased somatic cell count, improved cow cleanliness, improved cow comfort, improved production,

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ease of completing daily chores, and improved manure handling (Black et al., 2013; Leso et al., 2020). Galama et al. (2015) found that milk yield per cow is higher, fertility is better, and there are less claw and leg problems in CBP barns than in free stall barns. Because of the soft bed, cows in CBP barns have more freedom of movement, can exhibit heat better, and can lie down and get up more naturally (Janni et al., 2007) than when on concrete floors (Dippel et al., 2009). Lobeck et al. (2011) reported lower lameness prevalence in CBP housing (4.4%) than in free stalls (15.9%). Tebug et al. (2012) found lameness prevalence of 2.7% in dairy cattle in cubicle housing with concrete, brick, or clay flooring. This lameness (2.7%) could have been due to exposure to slurry or the effect of concrete (Tebug et al., 2012).

In most cases, softer surfaces such as in CBP housing could be more forgiving on the cow's feet and hocks than is concrete. Cows in CBP housing spend less time standing on concrete and do not have restrictions when lying or rising (Leso et al., 2020). Black et al. (2013), Galama et al. (2015), Eckelkamp et al. (2016) suggest that CBP housing have enormous potential to improve cow welfare (claw, hock, and udder health) when managed properly than if housed on concrete. Mastitis, lameness, and hock lesions are all important welfare issues globally. Sub-clinical mastitis is the most common form of mastitis and is the major concern compared with clinical mastitis (Tebug et al., 2012; Abebe et al., 2016; Biniam et al., 2015). Mastitis, lameness, and hock lesions can be used to assess animal welfare on dairy farms (Kawonga et al., 2012). Animal welfare is a state at which an animal can cope with conditions in which it lives. Animal welfare includes physical comfort, possibilities to perform natural behaviour, and absence from hunger and disease (Valente et al., 2020). Temperature-humidity index (THI) is used to analyse cow comfort (THI \leq 70: normal, THI between 72 and 78: warning situation, THI between 78 and 82: danger situation, THI $>$ 82: need for immediate intervention (Valente et al., 2020).

Although CBP housing have enormous potential to improve cow performance and welfare (claw, hock and udder health), many questions still exist about their management and viability, with one preeminent question being whether the compost bedded dairy housing is suitable in other dairy production systems such as in pasture-based systems. Climatic conditions and farm management vary; as such, the things that work in one place may not work in the other. High bacteria count, exposure to pathogens, and food contamination from spore-forming bacteria found in CBP barn bedding (Galama et al., 2015) are all critical factors for CBP housing in warmer environments (Black et al., 2014). Conditions that promote efficient composting in CBP housing are also favourable for pathogens (Black et al., 2014, Eckelkamp et al., 2016). Also, the compost present in the bed still is not the typical fully mature compost, since the aerobic layer is in the active composting phase

while the layer beneath is anaerobic and still active. To provide insights into this situation, a 6-month study with compost bedded pack dairy housing technology was conducted comparing cow performance and well-being under grazing or semi-grazing systems during the rainy and dry seasons.

MATERIALS AND METHODS

Study location

This study was conducted at a commercial farm in Lilongwe, Malawi at latitude 13.9°S and longitude 33.6°E from March 1 to August 30, 2017. Malawi has a sub-tropical climate which is characterized by two distinct seasons: the rainy season (November to April) during which 95% of the annual precipitation takes place and dry season (May to October). Soils in the study area are mostly alfisols with loamy sand texture and are moderately acidic (Snapp, 1998).

Design of the study

A single-system study was designed to assess the effect of management system (grazing "systems in which cows are kept at pasture for a large proportion (8 to 10 h; 33.33 to 41.67% of the day) vs semi-grazing "systems in which cows are kept indoors with (16.67% of the day) or without outdoor access", on dairy cattle performance and welfare in one commercial dairy herd. To examine the influence of management system, data of thirty-two loose-housed cows before and after changing to semi-grazing system during the rainy season (week 1 to 4; grazing, week 6 to 9; semi-grazing) and before and after changing to semi-grazing system during the dry season (week 11 to 16; grazing, week 18 to 23, semi-grazing) were examined.

Animal management

The CBP design (Figure 1) included an open composted pack, bedded with sun-dried sawdust from Duroblock sawmill in Lilongwe, feed alley, exercise area, and a 1.2 m high retaining wall. The CBP pack lying space per cow was 9.71 m². Sawdust was added based on the moisture guideline for composted beds (40 to 60%) (NRAES 1992). The bedded pack was tilled twice a day using a cultivator (Janni et al., 2007). Floors in CBP were manually cleaned daily at 0800 h by moving manure with a hand-held scraper while cows were at pasture. Cows were managed on pastures with additional pasture provided two times a day (1200 and 1700 h) when cows were managed under semi-grazing system. A concentrate prepared for all cows was provided during milking. All cows were milked twice a day (0200 and 1400 h) in a 2 x 12 milking parlor. Milking procedure includes teat cleaning with water, fore-stripping, pre-dip application, teat drying with a cloth, and milking unit attachment. Individual cow milk was weighed immediately after milking using a scale. The farm used a foot bath (copper sulphate) which was changed daily after evening milking.

Data collection

Milk yield

Individual milk yields were recorded daily for 6-month. Milk yield data for each cow was averaged to provide a weekly average per

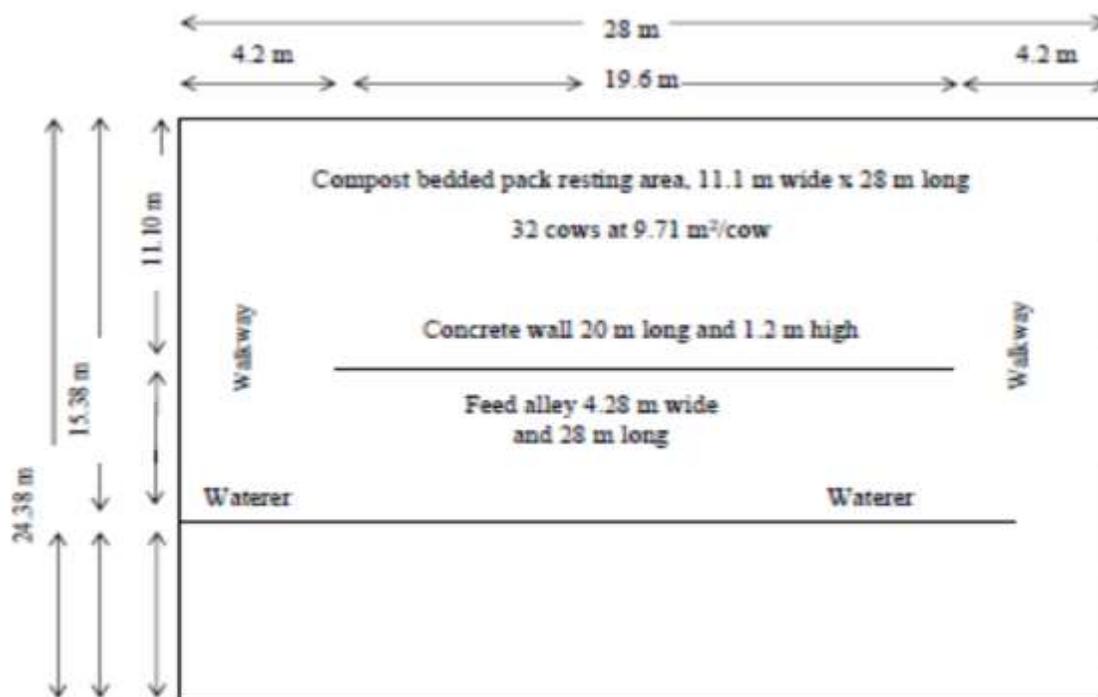


Figure 1. Compost-bedded pack housing layout with bedded pack, walkways and feed alley.

cow (kg).

Welfare and hygiene measurements

Cows were evaluated at weekly intervals by the same observer for lameness, hock lesions, and hygiene (animal-based measures of welfare). The degree of manure contamination on udder, lower leg, and upper leg and flank of all cows was assessed using a 1 to 4 scale (1 = clean, 2 = moderate dirt, 3 = plaques of dirt with hair visible, 4 = confluent plaques of dirt with no hair visible) (Barberg et al., 2007a). Hock lesions were evaluated in the parlor before milking unit attachment using 1-3 scale (1 = no lesions, 2 = mild lesion [hair loss], and 3 = severe lesion [swollen hocks with or without hair loss]). Hock lesion prevalence was calculated as the total number of cows with a hock lesion score greater than two divided by the total number of animals scored (Lobeck et al., 2011). All cows were assessed for lameness as they were exiting the parlor and as they walked on a flat area (Barberg et al., 2007a) using a 1-3 locomotion scoring system (1 = sound, 2 = mildly/moderately lame: visible gait abnormality, 3 = severely lame: obvious gait abnormality (NAHMS, 2015)). Prevalence of clinical lameness was calculated by dividing the number of cows with a locomotion score of 3 by the total number of cows scored each week (Barberg et al. 2007a).

Somatic cell counts

Milk samples were drawn aseptically (Black et al., 2014) teat ends were washed and dried using a clean cloth; teats were fore-stripped, pre dip was applied and removed with a clean cloth, and teat ends were cleaned with 70% isopropyl alcohol swab before drawing a 5 ml sample. Composite samples (10 ml) were analyzed for SCC on an Ekomiik scan somatic cells analyzer (Ekomiik Scan, BULTECHC 2000, Sweden) within three hours of milking. Composite

milk SCC of $\leq 200,000$ cells/ml was a threshold value for cows with all quarters free of subclinical mastitis (Smith, 1997). Sub-clinical mastitis prevalence was calculated as the number of animals with a test SCC $> 200,000$ cells/ml divided by the total number of animals scored each week (Barberg et al., 2007a; Leso et al., 2020). Milk SCC was log transformed to obtain a linear score using the following equation: $SCC = \text{Log}_2 (SCC/100000) + 3$ and was back transformed for interpretation.

Milk bacteria

Quarter milk samples were aseptically collected from cows with SCC $> 200,000$ cells/ml or cows with clinical mastitis as described by Black et al. (2014) based on NMC (1999) procedures for diagnosing bovine mastitis. A clinical mastitis case was defined as cows with visual signs of inflammation including swollen udder, redness or heat, abnormal milk, and/or presence of clots in milk. Milk samples were cultured for isolation of bacteria. A 1:10 dilution was prepared by placing 1 ml of milk sample into 10 ml of distilled water. Aliquot of 0.01 ml (10 μ l) were streaked onto one-half of MacConkey agar and blood agar plates using a sterile swab. Plates were placed in an inverted position in an incubator at 35°C for 24 h to 48 h.

Gram stains were performed to differentiate gram-positive and gram-negative bacteria. *Streptococcus agalactiae* were identified based on growth on blood agar, biochemical tests including hemolysis on blood agar, catalase test, acid production in broth containing different carbohydrates and Lancefield's classification by means of agglutination tests (group B: *S. agalactiae*). *Streptococcus dysgalactiae* were identified based on growth on blood agar, catalase test, and Lancefield's classification by means of agglutination tests (group C, *S. dysgalactiae*). *Klebsiella* spp were identified based on growth on blood agar (moist and mucoid) and growth on MacConkey agar (pink-yellow mucoid colonies), and

Table 1. Least square means (\pm SE) from the mixed model analysis showing the effect of management system on hygiene scores, somatic cell count, sub-clinical mastitis prevalence, lameness, hock lesions, and milk yield for loose-housed cows.

Measurement	¹ Management system		SEM	P value
	Grazing	Semi-grazing		
Hygiene scores	1.52	1.43	0.07	0.12
² SCC ($\times 10^3$ cells/ml)	646.11	534.38	91.89	0.22
Sub-clinical mastitis prevalence (%)	50.00	48.00	0.25	0.59
Milk yield (kg/d)	11.46	11.54	0.31	0.81
Lameness (%)	0.06	0.85	0.01	0.33

¹Grazing “systems in which cows are kept at pasture for a large proportion (8 to 10 h; 33.33 to 41.67% of the day), Semi-grazing “systems in which cows are kept indoors with (16.67% of the day) or without outdoor access”; ²Somatic cell counts were analyzed weekly. Cow milk SCC was log transformed to obtain a linear score using the following equation; $SCC = \text{Log}_2 (SCC/100000) + 3$.

Triple Sugar Iron reaction (acid slant, acid butt, and gas production).

To perform antimicrobial sensitivity tests for *S. agalactiae*, *S. dysgalactiae*, and *Klebsiella* spp, discs (tetracycline, novobiocin, chloramphenicol, streptomycin, penicillin, erythromycin, and fusidic acid) were applied on blood agar and inoculated with the pathogens. The discs were incubated at 37°C for 16-18 h. After 18 h, the discs were viewed for zones of inhibition (Tebug et al., 2012). The diameter of the zone of inhibition was measured (mm).

Barn environment

Temperature and relative humidity were measured and recorded by a temperature-humidity sensor (Hobo U23 pro V2, Onset Computer Corp, Bourne, MA) placed at the center point in the CBP housing (Figure 1). Temperature humidity index was calculated using the following equation defined by Ravagnolo et al. (2000): $THI = [(1.8 \times T) + 32] - (0.55 - 0.0055 \times RH \times (1.8 \times T - 26))$, where T is the dry bulb temperature in degrees Celsius, and RH is the relative humidity in percentage.

Statistical analysis

Data collected a week after cows changed from grazing to semi-grazing system in each season were removed before being subjected to statistical evaluation. Continuous variables such as cow hygiene, somatic cell count, and milk yield were analyzed as repeated measurements using the PROC Mixed Procedure of SAS (version 9.3, SAS Institute Inc., Cary, NC) using a restricted maximum likelihood model (REML) according to the following model;

$$Y_i = \mu + M_j + \epsilon_i$$

Where Y_i = an individual data point, μ = overall mean, M_j = management system ($j = 1$ to 2), ϵ_i = residual error.

To account for the individual variation of the cows, a repeated statement was included. Mastitis prevalence was analyzed as a repeated measure using the PROC GENMODE procedure in SAS (version 9.3, SAS Institute Inc., Cary, NC). PROC GPLOT in SAS (version 9.3, SAS Institute Inc., Cary, NC) was used to generate plots of mastitis prevalence rates. LSMEANS option in SAS was used to test differences between means. Statistical significance was declared at $P < 0.05$. Data were checked for normality of variance by visual plots. Analysis of outliers was performed using box plots.

RESULTS

One cow was culled due to sickness. Data of 31 cows were included in the final analysis. Table 1 shows average hygiene scores, milk yield, somatic cell count (SCC), mastitis prevalence, and lameness prevalence for cows under grazing or semi-grazing systems. Lameness prevalence did not differ between grazing and semi-grazing systems (0.06 vs 0.85%, respectively, $P > 0.05$). Hock lesion prevalence (proportion of cows with a hock lesion score > 2) was 0.00% for both grazing and semi-grazing system. Average milk yield did not differ between grazing and semi-grazing (11.46 vs 11.54 kg/day per cow, respectively, $P > 0.05$). Average hygiene scores did not differ between grazing and semi-grazing system (1.52 vs 1.43, respectively, $P > 0.05$). Average SCC did not differ between grazing and semi-grazing systems (646.11 vs 534.38 cells/ml, $P > 0.05$, respectively). Average sub-clinical mastitis prevalence did not differ between grazing and semi-grazing systems (50 vs 48%, respectively, $P > 0.05$). Temperature, relative humidity, and temperature humidity index (THI) trends for the CBP barn are described in Figure 2. Mean (\pm SD) THI inside the CBP barn was 67 ± 3.06 . Mean air temperature in the CBP was greater during the rainy season compared with the dry season (21.40 ± 3.19 vs 16.78 ± 1.93 , respectively, $P = 0.01$, Figure 2).

Table 2, shows the percentage of pathogens isolated from milk samples during the rainy and dry seasons. Contagious pathogens in milk samples during the rainy season was lower (14%) compared with environmental pathogens (82%). Environmental pathogens were lower (73%) during the dry season compared with the rainy season (82%). *Klebsiella* species were lower during the rainy season (54%) than during the dry season (72%). Sensitivity tests revealed that *Klebsiella* species were mostly sensitive to chloramphenicol, *S. agalactiae* were mostly sensitive to erythromycin, chloramphenicol, and fusidic acid, and *S. dysgalactiae* were sensitive to tetracycline, novobiocin, streptomycin, erythromycin, and

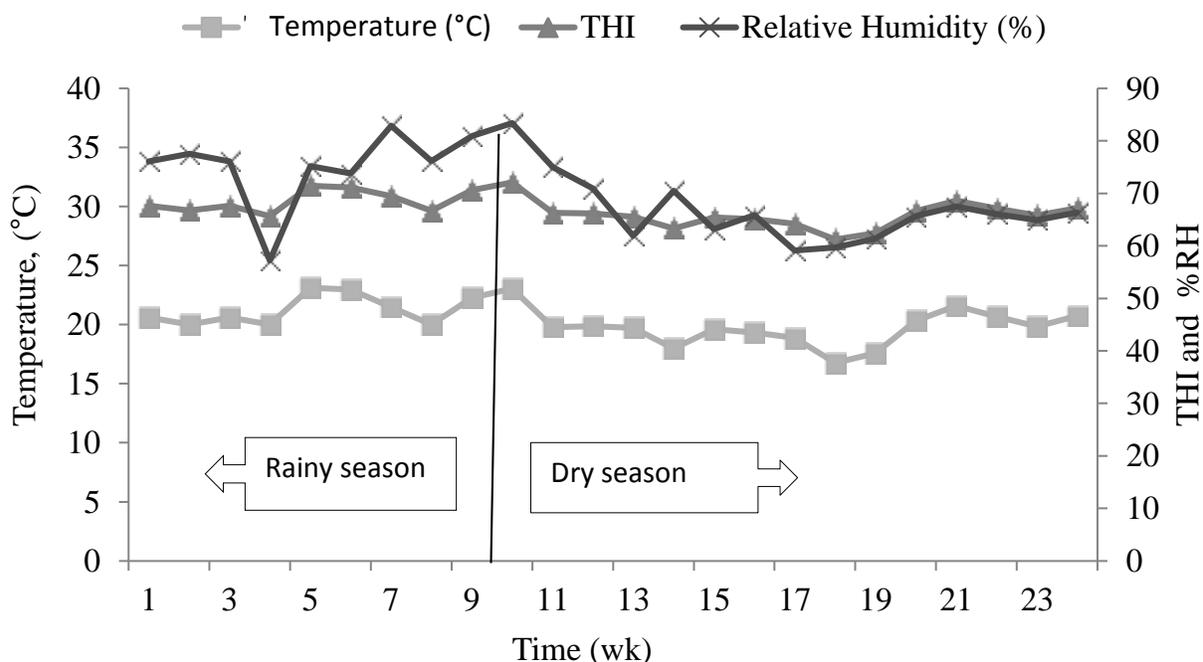


Figure 2. Average ambient temperature (°C), relative humidity (RH, %), and temperature-humidity index (THI) by week (March to August).

Table 2. Bacteria isolated from composite milk samples of lactating dairy cows during the rainy and dry seasons.

Bacteria	Season			
	Rainy season		Dry season	
	Frequency	Percentage	Frequency	Percentage
<i>Streptococcus agalactiae</i>	7	14	0	0
<i>Streptococcus dysgalactiae</i>	14	28	1	2
<i>Klebsiella</i> species	27	54	36	72
No growth	2	4	0	0

chloramphenicol.

DISCUSSION

The effects of management system (grazing vs semi-grazing) on performance and welfare in loose-housed dairy cows were examined on a single farm. Therefore, the results should not be generalized to a larger population. This study design was chosen for the purposes of obtaining data on the compost bedded pack barn, which is a newer housing concept (Janni et al., 2007; Leso et al., 2020). This study provided a detailed insight into the performance of CBP-housed cows with access to pasture under grazing and semi-grazing system. Further research using more definitive assessments are required. The subjects in this study

served as their own control, thereby providing detailed insight into the newer housing concept, the compost bedded pack housing technology. Single-system studies are often used in applied research to investigate the effect of an intervention. Further investigations on the CBP are needed using more farms to increase the power.

The present study revealed no difference in hygiene scores, SCC, mastitis prevalence, lameness, hock lesions, and milk yield between grazing and semi-grazing system. Lameness, hock lesions, cow hygiene, and udder health reflect the health and behaviour of animals in relation to the husbandry systems and environments in which they live (Buller et al., 2018). Increased housing period under semi-grazing in a CBP could have alleviated some of the negative attributes of confinement systems such as reduced lying time and increased cow dirtiness due to reduced cleanliness in housed environments

(Tebug et al., 2012; Ito et al., 2014; Banda, 2014). Softer lying surfaces such as in CBP provide comfort through surface softness and helps keep cows clean and healthy (Chaplin et al., 2000). Hygiene score and hock lesions scores were low for CBP-cows under grazing (1.52 and 0.00%) and semi-grazing (1.43 and 0.00%) similar to results of Costa et al. (2018) who found lower hock lesions in CBP (0.5%) than in free stalls (9.9%).

Contrary to the observed lower hygiene scores under semi-grazing (1.43) in the current study, Tebug et al., (2012) observed high hygiene scores for cows managed under semi-grazing mostly due to reduced cleanliness in housed environments (conventional cubicle housing). Banda (2014) showed that cows in conventional cubicle housing stand for most part of the day (13 h), which can lead to high accumulation of urine and feces, moisture on concrete or in the bedding can result in dirty cows (Tebug et al., 2012). Results on low hygiene scores (1.52 and 1.43 for grazing and semi-grazing respectively), in the current study agrees with studies with CBP housing that shows that cows are generally cleaner in CBP compared with cows in other housing systems such as free stall or cubicle housing (Barberg et al., 2007a; Lobeck et al. 2011; Black et al., 2013). Black et al. (2013) found hygiene scores of 2.2 ± 0.7 in CBP-housed cows and demonstrated that CBP can be a great environment for cows when properly managed.

Sub-clinical mastitis prevalence of 48% for semi-grazing and 50% for grazing were within the range of sub-clinical mastitis prevalence reported in other studies, 44.9% (Mekibib et al., 2010a), 48.1% (Tebug et al., 2012), 59.2% (Abebe et al., 2016), and 56.3% (Beniam et al., 2015). No difference was observed in SCC and mastitis prevalence between grazing and semi-grazing systems ($P > 0.05$). These results, however, are contrary to results of Tebug et al. (2012), who reported a difference ($P < 0.05$) in mean mastitis prevalence between animals managed under grazing and semi-grazing systems. Housing cows in the CBP under semi-grazing might have a positive effect on cow hygiene (1.43 on a scale of 1 to 4: 1 = clean, 2 = moderate dirt, 3 = plaques of dirt with hair visible, 4 = confluent plaques of dirt with no hair visible) (Barberg et al., 2007a) which is associated with udder health (Tebug et al., 2012). Also, the CBP offers animals a large, open resting area and a soft dry lying surface that increases cow comfort (Janni et al., 2007; Borchers 2018; Leso et al., 2020) and may reduce the risk for mastitis (Ruud et al., 2010).

Lameness was low (0.06% for grazing and 0.85% for semi-grazing), similar to other studies with cows housed on softer surfaces such as compost bedded packs, straw yards, or sand bedded stalls (Haskell et al., 2006a; Lobeck et al., 2011; Eckelkamp, 2014). Lobeck et al. (2011) noted that hock lesion prevalence and lameness were significantly high in free stalls (23.9%, $P < 0.001$ and 15.9, $P < 0.01$ respectively) than in CBP (3.8 and 4.4% respectively) because cows in CBP spend less time

standing on concrete. Further, compared with previous studies (Lobeck et al., 2011), cows housed in CBP had access to pasture during the study. Hernandez-Mendo (2007) assessed the effect of access to pasture on lameness. Cows showed improvement in gait compared with cows kept in confinement, even with a short period of access to pasture (over 4 weeks).

Mean air temperature (20.34 ± 1.79) and THI (67 ± 3.06) in the CBP environment were similar to air temperature and THI found in other studies with naturally ventilated CBP housing (Valente et al., 2020). Temperature (Figure 2) remained below critical upper temperature (25°C) (Valente et al., 2020). Mean THI in the CBP was below the thermal threshold for heat stress ($\text{THI} \leq 70$) in dairy cows (Wheelock et al., 2010). Mean milk yield of CBP-housed cows (10.89 ± 0.40 kg/day per cow) was consistent with milk yield in other studies (11 to 15 kg/day) (Banda, 2014). Similar to other studies (Tebug et al., 2012), milk yield between grazing and semi-grazing systems did not differ. Milk samples were cultured to identify pathogens associated with high SCC on the farm. The percentage of contagious pathogens in milk samples during the rainy season was lower (14%) compared with environmental pathogens (82%). Hygiene of the cow, the barn, and the grazing areas are important in determining whether pathogens invade the teat end or not. Less hygienic conditions during the rainy season could be a risk factor for mastitis caused by environmental pathogens (Tebug et al., 2012). Environmental pathogens were higher (82%) during the rainy season compared with the dry season (73%). High temperatures and relative humidity during the rainy season (Figure 2) might be important for cow hygiene and occurrence of mastitis (Eckelkamp et al., 2016). Tebug et al. (2012) found a lower percent (14.3%) of contagious pathogens compared with environmental pathogens (85.7%) in California Mastitis Test (CMT) positive milk samples.

Klebsiella species were the most common bacteria isolated in milk samples during both seasons (rainy and dry season, Table 2). *Klebsiella* species were lower during the rainy season than during the dry season (27 of 50 samples and 36 of 50 samples, respectively, Table 2). These results are consistent with other studies (Lobeck et al., 2012), showing that *Klebsiella* species are greater during the dry season compared with other seasons. Cows faced a risk of increased *Klebsiella* species, an environmental pathogen, during the dry season. However, producers could counteract the adverse effect of this by maintaining a dry resting surface, which has been shown to minimize teat end exposure to pathogens (Black et al., 2014). Sensitivity tests revealed that *Klebsiella* species were mostly sensitive to chloramphenicol. *S. agalactiae* and *S. dysgalactiae* were sensitive to tetracycline, novobiocin, and chloramphenicol.

Because clinical *Klebsiella* mastitis is less sensitive to antibiotics, keeping cows healthy is critical in managing *Klebsiella* species because well-nourished cows in stress

free environments will have stronger immune systems and will be capable of fighting off infections (Ruud et al., 2010).

Conclusion

The current study provided detailed insights into the performance of CBP-housed cows with access to pasture under grazing and semi-grazing system. These useful insights can be researched further using more definitive assessments. Cows faced a risk of increased *Klebsiella* species, an environmental pathogen that was less sensitive to antibiotics during the dry season. However, producers could counteract the adverse effect of this by maintaining a dry resting surface, which has been shown to minimize teat end exposure to pathogens. Focus on reducing somatic cell count will be critical in preventing mastitis infection.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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