J. Dairy Sci. 92:907–912
doi:10.3168/jds.2008-1157

Behavior and milk production of buffalo cows as affected by housing system

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ABSTRACT

To verify the effect of 2 housing systems (with and without a pool and an ample outdoor lot) on behavior and milk yield, 45 lactating buffalo cows were group-housed in a free stall open-sided barn with concrete floor where they received 10 m^2/head as space allowance (group NP); 43 cows were group-housed in a similar barn, but had access to an outdoor yard (36 m^2/head) and a concrete pool of 208 m^2 (group WP). Animals were subjected to 8 sessions of instantaneous scan sampling at approximately 10-d intervals. Behavioral variables were expressed as proportions of subjects observed in each category of posture and activity. In addition, rapid behaviors such as agonistic, social, and reproductive interactions, social licking, and self-grooming were recorded continuously. These variables were expressed as number of interactions per animal. At the end of each hour of observation, temperature and relative humidity were recorded. In WP the proportion of animals observed wallowing was 0.476 ± 0.034, whereas lower proportions were observed standing (0.389 ± 0.029) or lying (0.141 ± 0.021) outside the pool. In NP the proportions of animals observed standing and lying were 0.452 ± 0.042 and 0.548 ± 0.042, respectively. A significant relationship between mean temperatures recorded on observation days and proportion of animals in the pool was observed (r_s = 0.41). Fewer animals from group WP were observed idling compared with buffaloes from group NP (0.44 ± 0.024 vs. 0.509 ± 0.024, respectively), whereas more WP animals were involved in investigative activities than NP cows (0.099 ± 0.009 vs. 0.042 ± 0.009, respectively). A greater number of social interactions (sniffing and nuzzling) and social lickings were observed in group WP than in group NP (0.120 ± 0.010 vs. 0.067 ± 0.010, and 0.151 ± 0.018 vs. 0.090 ± 0.018, respectively). The WP buffalo cows had a greater milk yield than NP cows (11.73 ± 0.31 vs. 10.78 ± 0.28 kg/d, respectively), whereas no differences between groups were observed for protein (4.86 ± 0.04 vs. 4.80 ± 0.03% for WP and NP, respectively) and fat contents (8.49 ± 0.14 vs. 8.38 ± 0.13% for WP and NP, respectively). We conclude that the provision of a pool and an ample outdoor paddock can have beneficial effects on welfare and milk production of buffaloes.

Key words: dairy buffalo, animal welfare, behavior, milk production

INTRODUCTION

In Western countries dairy enterprises are facing a progressive saturation of markets that are consequently becoming very competitive. In Italy buffaloes (*Bubalus bubalis*) are used as dairy animals, because they have been selected for milk production and have acquired specific traits characteristic of the actual "Italian Mediterranean buffalo." The use of buffaloes is steadily increasing in terms of both numbers of animals and number of farms because of the economic returns coming from the transformation of milk in the traditional Mozzarella cheese and other innovative products (Addeo et al., 2007; Menghi et al., 2007). Therefore, buffaloes may represent a potential tool for dairy farms to differentiate products and increase competitiveness. In the past, buffalo husbandry was associated with depressed regions of southern Italy and considered suitable only for swampy areas. More recently, because of the economic interest, buffalo farming has moved from traditional techniques based on the extensive use of humid environments where either potholes or pools were available, to intensive systems that were developed for dairy cattle with no access to water for wallowing (De Rosa et al., 2005). It has been reported that buffaloes can acclimate more to hot than cold environments (Zicarelli et al., 2005). Through natural selection, buffaloes have acquired several morphological features that allow their adaptation to hot areas. For instance, melanin-pigmented skin is useful for protection against UV rays, and low hair density facilitates heat dissipation by convection and radiation. In hot, dry climates, low humidity determines intense evaporative heat loss, which in buffaloes is limited by the low number of sweat glands. In addition, respira-

Received March 6, 2008.
Accepted October 20, 2008.
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tory evaporation is less effective than in cattle due to induced alkalosis as a consequence of a rapid increase of blood pH (Koga, 1991). In contrast, in hot, humid climates, high humidity is paired with small diurnal changes in air temperature, and evaporative heat loss is not as effective in body heat dissipation. Thus, buffaloes rely on wallowing for efficient thermoregulation, as indicated by the high secretion of sebum that protects the skin while the animals are in the mud (Hafez et al., 1955). In particular, buffaloes in hot conditions increase blood volume and flow to the skin surface to maintain a high skin temperature and facilitate heat dissipation while in the mud or in the water (Koga, 1999). Little is known about the effect of insufficient heat dissipation on milk yield and reproductive performances of buffaloes, although in cattle, it was associated with reduced conception rate and milk production (Kadzere et al., 2002).

Intensification of buffalo farming techniques has led to a reduction of space allowance, compared with dairy cattle standards, with no specific studies on the real space requirements of this species. Space restriction can adversely affect various aspects of animal welfare such as health (increased levels of lesions and injuries), social behavior (increased number of agonistic interactions), and heat dissipation. Lack of space resulted in evidence of stress in different buffalo categories (calves, heifers, and cows). In these studies, the animals showed alterations in several behavioral and physiological responses because of space restriction (Grasso et al., 2003; Napolitano et al., 2004; Tripaldi et al., 2004).

Still, welfare is not simply limited to the function or performance. Animals should be able to develop normally and express natural adaptations in relation to their innate natures. The provision of barren housing systems irrespective of natural behaviors and needs may reduce the welfare of livestock, whereas it was suggested that the well-being of an animal might be improved through valuable experiences that makes life of the animal richer (Vaarst et al., 2001).

Although some studies assessed the effect of a pool or potholes on behavior and immunity of buffalo heifers (De Rosa et al., 2007) and on buffalo cow reproduction (Di Palo et al., 2001; Zicarelli et al., 2001), behavior (Tripaldi et al., 2004), and metabolic profile (Grasso et al., 2004), they did not consider the relationship with the environmental temperatures and the animal's need for thermoregulation. Thus, the present study aimed to verify the effect of 2 housing systems (with and without a pool and an ample outdoor paddock) on the behavior, reproductive performance, and milk yield of buffalo cows in relation to the surrounding temperature.

MATERIALS AND METHODS

Experimental Design

The experiment was conducted with 88 multiparous lactating buffalo cows from April to October 2005 in a farm located at Eboli, Salerno province, Italy (15°13′E, 40° 17′N; 5 m above sea level). Animals, with a parity of 3.2 ± 0.25 and a BW of 610.5 ± 8.8 kg at the start of the study, were equally allocated to 2 treatments. Animals were balanced for milk yield of their previous lactation. Forty-five buffaloes were group-housed in a free-stall open-sided barn with concrete floor where they received 10 m^2/head of space allowance (**NP**). The resting and feeding areas were covered by a roof, whereas the exercise area (35% of the total surface of the barn), located between them, was uncovered. Forty-three cows were group-housed in a similar barn, but had access to an outdoor lot with natural floor and 36 m^2/head as space allowance. The lot was provided with a concrete pool of 208 m^2 (**WP**). After parturition, experimental animals were separated from calves and allocated to either group where other lactating nonexperimental animals and 2 bulls were present. Nonexperimental animals were balanced for parity, BW, and stage of lactation. With all the animals (experimental + nonexperimental) combined, there were 90 buffaloes in each group. The 2 experimental groups were formed over a 3-wk period. Every day at 0900 h, subjects were offered a TMR for ad libitum consumption (Table 1). For each group 2 drinking troughs were available.

Behavioral Recordings

Behavioral observations were performed from June to August. Animals (90 for each group) were subjected to 8 sessions of instantaneous scan sampling at approximately 10-d intervals. Observations were made every 20 min over a 5-h period (1000 to 1500 h), giving a total of 16 sets of observations per session. On observation days, an observer for each group of animals walked slowly past the fence from a distance of 4 m and recorded (using binoculars 10 × 50, when necessary) postures: standing or laying for NP and standing, laying, or wallowing (i.e., lying in the pool) for WP; activity: feeding from the manger (selection, prehension, and mastication), drinking, ruminating, idling (opened or closed eyes, but no other overt activity), investigative activities (walking slowly with or without the neck lowered, often interrupted by stopping and sniffing the ground or the housing equipment), oral activities (licking or manipulating housing equipment), and, only for WP location such as in the barn (resting,

Table 1. Composition and chemical analysis (% of DM) of the TMR

Item	Composition, %	Milk FU[1]/kg of DM	CP	Crude fiber	NDF
Maize silage	63.8	0.80	8.0	32.0	53.0
Alfalfa hay	9.8	0.58	17.7	31.9	48.0
Flaked barley	8.6	1.23	11.6	5.0	16.3
Wheat middlings	8.6	1.08	18.1	9.9	37.9
Soybean meal	6.1	1.14	47.9	6.8	15.3
Straw	2.5	0.35	4.4	39.2	60.4
Mineral mix	0.6	—	—	—	—
Total	100.0	0.88	15.8	21.7	40.0

[1]1 milk forage unit (FU) = 7.11 MJ of NE_L.

exercise, and feeding areas) or in the lot. Because of the number of animals, distance, and wallowing, any attempt to recognize individual animals failed. Therefore, nonexperimental animals were scored, and behavioral variables were expressed as the proportion of subjects observed in each category of posture and activity calculated as (the number of animals displaying each posture and activity)/90 (total number of animals per group). In addition, rapid behaviors such as agonistic interactions (pushing, butting, or threatening), social interactions (licking, sniffing, or nuzzling), reproductive interactions (bull or cow sniffing the genital region or mounting), social licking (licking pen mates), and self-grooming were recorded continuously. These variables were expressed as number of interactions per animal. At the end of each hour of observation, temperature and relative humidity (**RH**) were recorded with a digital portable thermo-hygrometer (Model 1750-1/QM, Filotecnica, Salmoiraghi, Milan, Italy). Temperature-humidity index (**THI**) was computed according to the following formula (Ingraham et al., 1974): THI = $(1.8 \times \text{db} + 32) - (0.55 - 0.55 \times \text{RH}) \times [(1.8 \times \text{db} + 32) - 58)]$, where db is dry bulb temperature in °C and RH the relative humidity expressed as a percentage.

Milk Production and Reproductive Performance

Animals were milked twice daily at 0430 and 1630 h in a 4 + 4 tandem parlor using pipeline milking machines. Daily milk yield, and milk fat, protein, and SCC were determined at monthly intervals from June to September. Milk yield was recorded by means of graduated measuring cylinders attached to individual milking units. Subsequently, individual milk samples were withdrawn from cylinders and placed in 40-mL plastic containers. Samples were analyzed for fat and protein content (IDF, 1990) using an infrared spectrophotometer (MilkoScan 605; Foss Electric, Hillerød, Denmark) and SCC (IDF, 1995) using a Somacount 300 (Bentley Instruments, Chaska, MN).

Pregnancy rate was calculated using the ratio between pregnant and nonpregnant animals as assessed by the 2006 calving calendar. Days open were calculated as the difference between the 2006 and 2005 calving dates minus the gestation length (310 d). The herd was managed using the out of breeding season technique, a common farming practice in southern Italy, which allows concentrating buffalo parturitions in spring and summer when the price of buffalo milk is highest. The technique consists of including the bull in the herd from March to October only, as buffaloes are seasonal and tend to mate in autumn.

Statistical Analysis

Data were analyzed with SAS software (SAS Institute, 1990). Due to the lack of individual recordings, behavioral data were analyzed using the day of observation as the experimental unit with treatment (WP and NP) and period of observation (1000 to 1220 h and 1240 to 1500 h) as main factors. For all other dependent variables, the cow was used as the experimental unit. Behavioral activities were analyzed using an ANOVA with 2 factors (treatment and period of observation). An angular transformation was used to homogenize variance of investigative activities. As to postures, standing and lying were subjected to ANOVA with 2 factors (treatment and period of observation), whereas wallowing was analyzed only for WP using an ANOVA with 1 factor (period of observation). Milk data were analyzed with ANOVA for repeated measures with treatment (WP and NP) as a nonrepeated factor and time (June to September) and time × treatment interaction as repeated factors. Logarithmic transformation for SCC was used to normalize skewness. For pregnant animals, days open were analyzed by ANOVA with one factor (treatment). Where appropriate, the *t*-test was used to identify differences between least squares means. Pregnancy rate between treatments was analyzed using a χ^2 test. Finally, for each treatment, correlations between climatic variables (mean temperature, RH, and THI) and postures were obtained using the Spearman rank coefficient.

RESULTS AND DISCUSSION

Behavioral Recordings

Mean (± SE) temperature, RH, and THI recorded during the behavioral observations were 28.8 ± 0.8°C, 62.1 ± 4.9%, and 78.4 ± 1.0, respectively.

Postures of the buffaloes during the observations for standing were not different between groups ($P > 0.05$). Yet, a lower proportion of buffaloes from WP (0.141 ± 0.021) was observed lying outside the pool as compared with the proportion of lying animals from NP (0.548 ± 0.042; $P < 0.001$). This result may be due to animals from WP resting while wallowing (0.476 ± 0.034; i.e., lying in the pool). In addition, no effects of period of observation and interaction were detected for standing and lying ($P > 0.05$).

In WP the proportion of animals observed standing (0.389 ± 0.029) was not different from the NP standing (0.452 ± 0.042). No effect of period of observation was observed for wallowing ($P > 0.05$), possibly because recordings were all performed during the hot part of the day (1000 to 1500 h). A significant relationship between mean temperatures recorded on observation days and proportion of animals in the pool was observed (r = 0.41, $P < 0.05$). An opposite trend was observed for standing (r = −0.42, $P < 0.05$). Conversely, no correlation was observed for THI index and RH with wallowing and standing. No correlations with climatic variables were detected for lying. These results indicate that buffalos use wallowing as a means to dissipate heat; conduction (direct contact of the skin with the water or mud) seems the most efficient tool for buffalo thermoregulation in hot conditions. For NP no significant correlations were observed between postures and climatic variables.

The prevalent location of the buffaloes from WP indicated that they prefer to stay in outdoor lots with a natural floors when available (proportion of animals located outdoors: mean ± SE = 0.634 ± 0.041).

Table 2 shows the effect of housing system on behavioral categories recorded using scan sampling techniques. The proportion of idling animals was higher in NP than in WP ($P < 0.05$), whereas there was no influence of period of observation on this behavioral activity. Subjects provided with a pool were more often involved in investigative activities than buffaloes without access to it ($P < 0.001$). Buffaloes are motivated to explore and investigate the environment (Napolitano et al., 2004). They often revisit familiar areas presumably to check for changes. Therefore, low levels of exploration can be seen as a sign of deprived adaptation to the environment.

Table 2. Effect of housing system[1] on behavioral categories observed over 5-h periods in 8 sessions[2]

Item	NP	WP	SE	*P*-value
Investigative activities	0.042	0.099	0.009	<0.001
Idling	0.509	0.444	0.024	<0.05
Feeding	0.149	0.179	0.020	0.276
Ruminating	0.272	0.250	0.015	0.294
Drinking	0.018	0.022	0.002	0.287

[1]NP = free stall open-sided barn; WP = free stall open-sided barn with outdoor lot and concrete pool.

[2]Data (least squares means; n = 16 for each group) are expressed as proportion of animals observed in each category.

Social activities are in Table 3. A greater number of social interactions (sniffing and nuzzling) and social lickings were observed in WP than in NP ($P < 0.01$ and $P < 0.05$, respectively). There are behavioral and physiological systems supporting beneficial and health-promoting positive social interactions. Active systems involved in the maintenance of positive components of homeostatic physiology are based on neural functions sustained by hormones such as oxytocin, vasopressin, and opioids (Carter, 1998). Social licking can play a role in reinforcing and stabilizing social relationships, thus functioning as cohesive interaction (Wasilewski, 2003). In WP the presence of a pool along with a greater space allowance may have promoted nonagonistic social interactions, thus encouraging the development of affinity relationships among buffaloes, which increased the cohesion of the group. Surprisingly, agonistic interactions were more often observed in WP animals than in NP subjects ($P < 0.01$). In general, a lack of space increases aggression levels within a group, possibly because the ability of subordinate animals to withdraw from dominant subjects is reduced. In the present study the level of aggression was low (0.16 vs. 0.08 for WP and NP, respectively) possibly a consequence of the space allowance, which was always over 10 m^2. Because buffaloes are social animals and live in herds, nonagonistic and agonistic interactions between members of the group contribute to establishing and maintain the social structure. Therefore, agonistic interactions can be regarded as natural behaviors and either very high or very low frequencies may be considered indicative of a suboptimal social environment (Laister et al., 2006).

Self-grooming behaviors were proposed by Knierim et al. (2001) as a potential indicator of optimum welfare; if the flooring is slippery, animals are inhibited in turning around their head, bending the spine, and spreading their legs, because they are more likely to lose balance. The presence of natural flooring may have

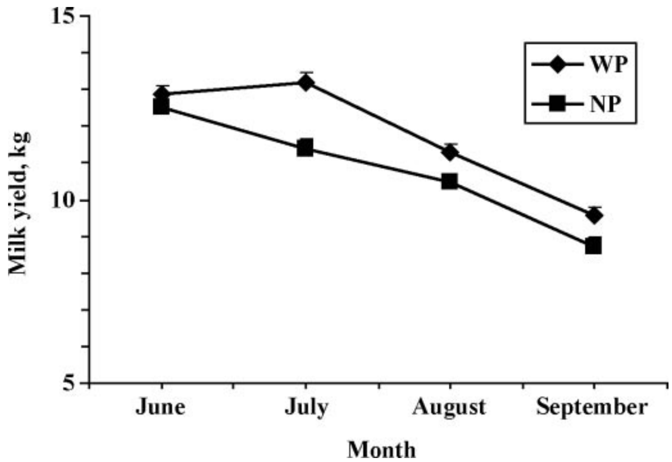

Figure 1. Effect of housing system (NP = free stall open-sided barn; WP = free stall open-sided barn with outdoor lot and concrete pool) on milk yield (least squares means ± SE; n = 45 and 43 for group NP and WP, respectively).

facilitated the expression of self-grooming in WP as compared with NP ($P < 0.01$). In addition, bathing and wallowing in the pool could have induced a higher proportion of buffaloes performing integumentary care, as self-grooming is often associated with body muddiness (Sato et al., 1991).

Milk Production and Reproductive Performances

As expected, milk production decreased throughout the experimental period ($P < 0.001$) as a consequence of the progression of lactation. The WP cows had a greater milk yield than NP cows (11.73 ± 0.31 vs. 10.78 ± 0.28, respectively; $P < 0.05$), whereas no differences between the groups were observed for protein (4.86 ± 0.04 and 4.80 ± 0.03%, respectively) and fat (8.49 ± 0.14 and 8.38 ± 0.13%, respectively) contents. For milk yield (Figure 1) there was a significant group by time interaction ($P < 0.05$) that can be attributed to the lack of differences between groups at the first recording (June, mean monthly temperature = 21°C; milk yield = 12.9 ± 0.2 and 12.5 ± 0.2 kg for WP and NP, respectively), whereas milk production was greater in WP than in NP at the second (13.2 ± 0.2 and 11.4 ± 0.2, respectively; $P < 0.001$), third (11.3 ± 0.2 and 10.5 ± 0.2, respectively; $P < 0.05$), and fourth recording period (9.6 ± 0.2 and 8.7 ± 0.2, respectively; $P < 0.05$) performed in July, August, and September and corresponding to 24, 23, and 22°C monthly mean temperatures, respectively. These results suggest that the positive effect of the pool was more evident when temperatures were higher. According to Shafie (1985), the climatic comfort zone for water buffalo ranges from 15 to 20°C. Therefore, the increased milk yield observed in WP may be due to the increased ability of the animals provided with a pool to thrive in hot, humid conditions such as summer in southern Italy. In dairy cattle, effective heat dissipation can induce more efficient energy utilization and a greater milk production (McDowell et al., 1976). In this species, high ambient temperatures were associated with less feed intake, reduced metabolic rate, and declining daily milk production, which represent strategies to maintain normal body temperature (Kadzere et al., 2002).

The higher space allowance offered to WP animals may have played a role in milk yield; a positive correlation between space allowance and milk production was observed by Zicarelli et al. (2005). Nevertheless, the greater incidence of agonistic interactions observed in WP suggests that the positive effect on milk production was likely mediated by a more efficient thermoregulation rather than by a less agonistic social environment. In addition, social licking may be beneficial to recipients, as demonstrated by increased milk production and weight gain observed in cattle receiving more grooming (Sato, 1984). Accordingly, in this study a greater number of social licking and social interactions per animal was observed in WP.

Somatic cell counts tended to be higher in WP (202,600 ± 15,800 vs. 156,941 ± 14,393; $P < 0.10$).

In a previous study the presence of a pool decreased the percentage of nonpregnant buffalo cows (Di Palo et al., 2001); in this study WP and NP had similar pregnancy rates (68.0 and 68.7, respectively; $P > 0.05$) and number of days open (91.8 ± 8.3 and 91.0 ± 9.4, respectively; $P > 0.05$). Environmental temperatures may have been not high enough to affect buffalo reproductive performances.

Table 3. Effect of housing system[1] on social interactions observed over 5-h periods in 8 sessions[2]

Item	WP	NP	SE	P-value
Social licking	0.151	0.090	0.018	<0.05
Agonistic interactions	0.157	0.085	0.016	<0.01
Reproductive interactions	0.088	0.115	0.019	0.36
Self-grooming	0.837	0.676	0.041	<0.01
Social interactions	0.120	0.067	0.010	<0.01

[1]NP = free stall open-sided barn; WP = free stall open-sided barn with outdoor lot and concrete pool.
[2]Data (least squares means; n = 16 for each group) are expressed as number of interactions per animal.

CONCLUSIONS

The present study showed that when buffaloes have free access to a pool, wallowing represents the preferred posture, possibly because it represents the most important means to dissipate heat, as indicated by the positive relationship between the environmental temperature and the proportion of animals in the pool. Animals provided with a pool and an ample outdoor space were more often involved in investigative activities and showed a higher number of social interactions (sniffing and nuzzling) and social lickings than cows without access. The presence of a pool was associated with greater milk production in July, August, and September, whereas no differences were observed in June. Effective heat dissipation through wallowing may have contributed to sustain buffalo milk production. We conclude that the provision of a pool and an ample outdoor lot can have beneficial effects on behavior, welfare, and milk production of buffaloes, and their inclusion in farms located in hot areas is recommended.

ACKNOWLEDGMENTS

The authors thank Gaetano Iemma for hospitality, Vincenzo Carbone for help in management of animals, Aniello Sorrentino, Davide Nicodemo, and Tommaso Cervone for help in behavioral recordings, and Giovanni Migliori for expert technical assistance. Special thanks to the referees and the editor for improving the quality of the manuscript.

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