Body condition scores at calving and their association with dairy cow performance and health in semi-arid environment under two cooling systems

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Abstract

Under tropical environments cow’s body condition at calving may influence productivity and health performance. Therefore, the current research evaluated the impact of body condition score (BCS) at calving on milk production traits and health problems of primiparous and multiparous cows raised under two cooling systems in semi-arid environment. Milk yield parameters and health disorders data at different parities were obtained from 1700 Holstein cows, which were managed under Korral Kool (KKC) and fan (FC) cooling systems in Saudi Arabia. The results revealed that KKC system induced high level of milk production improvement (305ST, days in milk, daily milk yield) (P<0.05) compared to FC, especially in multiparous cows. There was an advantage of the high BCS group under KKC system over the FC system for peak yield and period. Cows from both cooling systems having moderate BCS outdid the other groups for total milk yield. Low BCS primiparous cows reared under KKC system were the most to suffer from stillbirth (18%), and calving ease (26.1%) in winter, while high BCS were the most to be treated for mastitis (8.5% in summer). On the other hand, spring calved multiparous cows raised under FC system suffered more from lameness (21.57% - high BCS) and milk fever (4.4% - moderate BCS). Further, cows having moderate BCS kept under KKC system had the highest incidence of lameness (62.2%), and abomasum displacement (4.4%). In conclusion, achieving correct BCS at calving and cooling system is important to avoid calving subsequent lactation performance and metabolic disease losses.

Introduction

Dairy cattle in many tropical, subtropical and semi-arid environments are subjected to high ambient temperatures and intense solar radiation for extended periods. This results in heat stress on high producing dairy cows (Collier et al., 2006). Evaporative cooling systems provide protection from solar radiation, cool the immediate air surrounding the cow, and improve animal performance. Korral Kool (Mesa, AZ, USA) holding pen cooling and exit lane cooling past the milking period with overhead sprinklers and large fans are alternative cooling systems that would benefit the majority of dairy farms (Armstrong et al., 1988; Armstrong, 1994). Moreover, body condition score (BCS) provides a quick, cheap and easy method for evaluating and improving performance of dairy herds under different management systems, seasons or environments (Amer, 2008). Some studies indicated that BCS at calving was strongly related to health, reproduction and milk production as well as milk curve parameters (Markusfeld et al., 1997), while others reported no effect on milk yield, and health status, or negative correlation between milk yield and body condition (Mikóne et al., 2013).

The impact of BCS on subsequent health condition, dairy production and fertility had been evaluated by many researchers who recorded that low BCS suppressed peak milk yield and milk production traits in dairy herds, but cows with high BCS had no advantage in milk production (Flammenbaum et al., 1995). While Bayram et al. (2012) reported that milk yield, corrected 305 milk yield (305MY) and daily milk yield (DMY) of cows with low BCS at calving were significantly higher than those with moderate BCS. Mushlaq et al. (2012) indicated that higher milk yield was strongly supported by moderate BCS. Somatic cell count (SCC) as a measure of the concentration of leukocyte cells in milk and clinical mastitis are indicators of a cow’s udder health status. The BCS did not significantly affect the average somatic cell scores (SCS). However, Berry et al. (2007) noticed that the greater the increase in BCS at calving the lower the SCS in primiparous rather than multiparous dairy cows.

Research results concerning the relationship between body condition at calving and metabolic disease incidence and culling are controversial. Ruegg and Milton (1995) did not record any significant consequence of BCS at calving on disease occurrence. However, over-conditioned cows (BCS≥4.0) were not productive and had higher risks for metabolic problems (Gillund et al., 2001). Furthermore, the interaction between BCS at calving and parity was consistent with a lack of milk fever in primiparous cows (Roche and Berry, 2006). According to Hoedemaker et al. (2009) cows with low BCS at calving were more liable to lameness.

Several studies dealing with the effect of BCS at calving for cows reared under different cooling systems on dairy production and metabolic disease incidence are few and conflicting. Therefore, the current research objectives were to investigate the influence of different cooling systems and BCS on milk production traits, somatic cell count and scores, lameness, mastitis, metabolic disease incidence, and risk factors at different calving seasons in highly producing primiparous and multiparous dairy cows in a semi-arid environment of Saudi Arabia.

Materials and methods

Herd history and management

Data on productivity and health records were collected from different lactation seasons...
of Holstein Friesian commercial dairy herds situated in a semi-arid environment and central region of Saudi Arabia, from 2005 to 2011. Two main modern Holstein Friesian dairy farms in the same district were used in this study. Cows of the two farms are raised under ideal management conditions and bred via artificial insemination with high selected graded semen from the same breed.

The first farm having evaporative cooling systems, with fixed overhead coolers and variable-speed fans (Korral Kool) with water fountains, and cows exposed to cold water bathing just before entering the milking parlour was considered as KKC system (1000 cows, 200 primiparous and 800 multiparous cows). While, the second farm using sheds, fans, holding pen cooling and exit lane cooling was considered as FC system (700 cows, 150 primiparous and 550 multiparous cows). A unique feature of the cooling system in this arid climates is that as ambient temperature increase the aptitude of the cooling threshold increase. Water was available all time via common water troughs found under the shaded area. The cows were fed ad libitum twice a day. The daily fed ration to cows was formulated with TMR (total mixed ration) Tracker based feed management system (online data link). Composition of forages, good quality corn silage and soybean meal were determined by feed analysis center. The ration was formulated taking into account feed composition, pregnancy and lactation status, milk yield and composition, and the BCS to meet the National Research Council (2001) recommendations.

Cows were machine-milked in a herringbone parlour. Udder, belly and the area between the udder and hind limb were washed with water. Pre and post milking teat dipping was carried out and cows were subjected to strip cup testing and milked three times daily. Recording system used in the farm was computer program systems. Milk yield was recorded individually at each milking for three days per week, then daily and weekly milk averages were calculated for each cow. Detailed information about herd management, the temperature-humidity index, culling system, breeding of heifers and cows has been described by Mandour et al. (2012). Dairy cows at calving in the farms under investigation were subjected to BCS evaluation (two weeks post-partum) by two accredited veterinarians according to the system proposed by Edmonson et al. (1989) (1-5 with an interval of 0.25). Cows were finally grouped into three main classes (to obtain a greater approximation): low (≤3), moderate (3.25-3.75), and high (>4) BCS (Gallo et al., 2002). Milk samples were collected at the 30th day post-partum and SCC was determined individually by the fluoro-opto-electronic method (Fossomatic 180; Foss Electric, Hillerød, Denmark). Since SCC has shown a highly skewed distribution, SCC was converted to SCS through a base 2 logarithmic transformation (Ali and Shook, 1980):

$$SCS = \log_2 \text{(SCC/100)} + 3$$

The incidence of lameness, mastitis, milk fever, abomasum displacement, ketosis, abortion, calving ease, and stillbirths cases was registered by herd veterinarian and recorded from dairy cows records. Metabolic and other diseases (ketosis, mastitis, milk fever, etc.) were identified and diagnosed by a veterinarian, according to cow case history, clinical examination, cowside tests and biochemical analysis of blood serum.

### Dairy performance parameters

From each cow only complete records were kept for statistical analyses (total 9082 records); data were sorted according to cooling systems (KKC vs FC), body condition scores, calving season, and parity (primiparous vs multiparous) as following:

- total milk yield (TMY) during lactation length, days in milk (DIM)
- Daily milk yield (DMY)=TMY/DIM
- 305MY=[TMY/(DIM+100)]*405

(Mandour et al., 2012)

Other milk parameters were also considered: peak period, peak milk yield (the highest value of milk produced by a cow), days to peak (from beginning of lactation till the cow reached the peak milk production).

### Statistical analysis

All continuous data measurements were subjected to descriptive statistics using PROC MEANS, then statistically analysed by using the multivariate, general linear model (GLM) of SAS program (SAS, 2006). The statistical model included all fixed effects of cooling systems, BCS, season of calving, parity, year and their interactions:

$$Y_{ijklm} = \mu + C_i + B_j + P_k + S_l + Y_m + (CB)_{ij} + (CBP)_{ijk} + e_{ijklm}$$

where, $Y_{ijklm}$=observed value of the dependent variable; $\mu$=overall mean; $C_i$=cooling system effect (KKC and FC); $B_j$=BCS group effect (low, moderate, and high); $P_k$=parity effect (Primiparous vs multiparous); $S_l$=calving season effect (summer, fall, winter, and spring); $Y_m$=year effect; $(CB)_{ij}$=cooling system * BCS group interaction; $(CBP)_{ijk}$=cooling system * BCS group * parity interaction; $e_{ijklm}$=experimental error of random distribution ($0,\sigma^2$).

The risk of disease occurrence was estimated through the odds ratio (OR), after performing multivariate logistic regression analysis, using the LOGISTIC procedure in SAS (2006) to model the effects of cooling system, parity, BCS, calving season, DMY, SCS, year, and the effect of some associated diseases on the presence or absence of mastitis and lameness. Data were coded in binary form: 0 for absence and 1 for the presence of one or more of the variables or effects in the postulated model were done and modified after Gallo et al. (2002).

### Results

#### Summary statistics

Table 1 shows the main characteristics of the 2 herds under investigation. The overall average of TMY was 13,032±2934 kg/cow, being higher in KKC cow group (13,462 kg/cow) than in FC (12,865 kg/cow). The 305MY and average DMY followed the same pattern as TMY. They were 11,182, 12,207, 10,677 kg for TM305 and 37.03, 39.8, 36.1 kg/cow for average DMY, respectively. The overall average of DIM and peak period were 349 and 26.48 days, being longer in FC (359, 27.1 days) than KKC (341, 25.7 days). The average BCS at calving, SCS and peak yield of the 2 cooling systems were very close to those of the overall average, being 3.5, 21.51 (10*4), and 40.05 kg, respectively. On the other hand, high variation of the SCC was noticed. It was 26.5±7.8×10*4 for the FC system group, being the least in the KKC cow reared group, while the average was 21.51±6.22×10*4 (Table 1).

#### Cooling system and body condition score effect

Rearing dairy cows with different BCS under KKC system had shown significant (P<0.05) improvement in milk production traits more than those kept under the FC system. However, DIM of all BCS groups, days to peak yield for low BCS group, and peak period for high BCS groups were significantly higher in the FC system than in KKC. It was also noticed that cooling system significantly affects the peak yield and period, for the high BCS group of KKC (41.59±0.79 kg and 27.33±1.33 days) and FC (43.1±0.33 kg and 38.72±1.49 days) systems as well as the low BCS for KKC (38.35±0.35 kg and 23.14±0.68 days) and FC systems (36.73±0.60 kg and 18.17±1.1 days) (P<0.05) (Table 2).
Within both cooling systems, significant differences (P<0.05) were detected between the three BCS groups for 305MY, TMY, DIM and DMY, showing the least 305MY and TMY for low BCS group reared under FC system (7913±137.8 and 10319±155.9 kg), but being the highest in the KKC system of the high BCS group (12633±33.3 and 13880±64.76 kg). Furthermore, KKC system improved the dairy cow environment and increased their average DMY (41.0±0.11 kg) in the high BCS group. Still, rearing cows under FC system reduced it to 28.6±0.42 kg in low BCS and increased peak yield and period (43.1±0.33 kg and 38.7±1.49 days) in high BCS group (Table 2).

Moreover, milk production trait improvement was associated with high SCS in the low BCS group, except for the moderate and high BCS groups as cows reared under FC system had higher SCS than those kept under the KKC system (2.55±0.13 vs 1.79±0.06). Somatic cell count followed the same pattern as SCS; low BCS group averaged 13.53±1.11x10^4 under KKC system and 26.5±4.83x10^4 under the FC system (Table 2).

### Table 1. Summary statistics for different milk production traits of cows reared under two cooling systems.

| Milk production traits | KKC Mean | SD | FC Mean | SD | Total Mean | SD |
|------------------------|----------|----|---------|----|------------|----|
| 305MY, kg              | 38.35±0.35AX | 41.33±0.30AX | 41.59±0.79AX |
| DIM, days              | 23.14±0.68AX | 27.59±0.74AX | 27.33±1.33AX |
| TMY, kg                | 13572±22.58AX | 13807±40.57BX | 13880±64.76CX |
| DMY, kg                | 39.7±0.06AX | 39.9±0.08BX | 41.0±0.11CX |
| Days to peak, days     | 2516±4.83AX | 3289±4.83AX | 3289±4.83AX |
| Peak period, days      | 1573±2.36AX | 3289±2.36AX | 3289±2.36AX |
| BCS                    | 6065±3.5AX | 3289±3.5AX | 3289±3.5AX |
| SCC 10^4               | 2814±19.1AX | 2814±19.1AX | 2814±19.1AX |
| SCS                    | 2814±2.36AX | 2814±2.36AX | 2814±2.36AX |

KKC, Korral Kool cooling; FC, fan cooling; SD, standard deviation; 305MY, corrected 305 milk yield; DIM, days in milk; TMY, total milk yield; DMY, daily milk yield; BCS, body condition score; SCC, somatic cell count; SCS, somatic cell score.

### Table 2. Effect of body condition score on milk production traits of cows reared under two cooling systems.

| Milk production traits | Cooling system | BCS groups |
|------------------------|----------------|------------|
|                        | Low            | Moderate   | High       |
| 305MY, kg              | KKC            | 12301±19.4AX | 12062±24.8AX | 12633±33.9AX |
|                        | FC             | 7913±137.8AX | 11491±59.2AX | 11717±74.7AX |
| DIM, days              | KKC            | 344±0.32AX  | 333±0.51AX  | 338±0.60AX   |
|                        | FC             | 361±0.80AY  | 365±0.75AY  | 345±1.26AY   |
| TMY, kg                | KKC            | 13572±22.58AX | 13807±40.57BX | 13880±64.76CX |
|                        | FC             | 10319±155.9Y | 13177±28.51Y | 12832±80.97Y |
| DMY, kg                | KKC            | 39.7±0.06AX | 39.9±0.08BX | 41.0±0.11CX |
|                        | FC             | 28.6±0.43AX | 38.2±0.18AX | 37.4±0.25Y  |
| Days to peak, days     | KKC            | 53.5±0.95AX | 56.1±0.92AX | 57.4±2.01AX |
|                        | FC             | 55.0±1.33DX | 49.8±1.26Y  | 50.57±1.31Y  |
| Peak yield, kg         | KKC            | 38.35±0.35AX | 41.33±0.30AX | 41.59±0.79AX |
|                        | FC             | 36.73±0.60AX | 40.2±0.37AX  | 41.0±0.33Y   |
| Peak period, days      | KKC            | 23.14±0.68AX | 27.59±0.74AX | 27.33±1.33AX |
|                        | FC             | 18.17±1.10AY | 26.15±0.95Y  | 38.72±1.49Y  |
| SCC 10^4               | KKC            | 13.53±1.11AX | 25.18±2.46AX | 19.19±3.06AX |
|                        | FC             | 26.50±4.83AX | 29.54±9.22AX | 24.02±6.26AX |
| SCS                    | KKC            | 1.79±0.06AX | 2.45±0.21AX | 2.55±0.14AX |
|                        | FC             | 2.55±0.13AX | 2.72±0.06AX | 2.47±0.18AX |

BCS, body condition score; KKC, Korral Kool cooling; FC, fan cooling; 305MY, corrected 305 milk yield; DIM, days in milk; TMY, total milk yield; DMY, daily milk yield; SCC, somatic cell count; SCS, somatic cell score. x,yDifferent letters between cooling systems are significantly different (P<0.05); a-cDifferent letters among BCS groups are significantly different (P<0.05). Values are expressed as least square means±standard error.
calving cows had the highest SCC (25.3±2.49x10^4) as well as SCS (2.47±0.07), while autumn calved ones had the least SCC (13.05±2.8x10^4), and SCS (1.79±0.1) as well as peak period (24.79±1.35 days) (P<0.05).

**Parity effect**

Both heifers and mature cows showed significant variations for all BCS groups in 305MY, DIM, TMY, peak yield and period (Figure 1). Yet, cows surpassed heifers in TMY in both moderate (13759 vs 13143 kg) and high BCS group (14040 vs 12327 kg); heifers having low BCS had higher TMY (13468 vs 1412 kg). It was also shown in Figure 1 that cows had more milking days than their corresponding heifers for all BCS groups under investigation. On the other hand, calculated 305MY as well as DMY showed reversed results as heifers had higher values over their contemporary mature cows at low, moderate and high BCS groups. Heifers spent more days to reach peak yield (55.9 days) than mature cows (48.5 days) of the low BCS group. In addition, heavy weight heifers also had more peak period (40 days) compared to cows (34.5 days), but moderate BCS cows had 28.2 days in peak compared to heifers (23 days) of the same group.

**Metabolic disorders and other diseases**

Significant variations were observed between different BCS groups of primi or multiparous cows reared under the FC system for the incidence of calving ease (assistance), lameness and milk fever (Figure 2). However, more complications were recorded for those reared under KKC system, especially for calving ease, stillbirth, abortion, lameness, and abomasal displacement (Figure 2). Primiparous cows having low BCS, reared under KKC system had the highest frequency for assistance (n=261, 26.1%) and stillbirth (n=180, 18%). Further, high BCS cows kept under KKC system suffered more from mastitis (n=85, 8.5%), and those kept under Fc system had less frequency of ketosis (n=26, 3.71%). Whilst, multiparous cows having high BCS and reared under FC system complained most from lameness (n=151, 21.57%), and abortion (n=41, 5.86%). At the same time, moderate BCS cows reared under KKC system showed the highest incidence of lameness (n=622, 62.2%) and abomasum displacement (n=44, 4.4%); while those reared under the FC system were subjected to higher incidence of milk fever (n=52, 7.43%) (Figure 2).

Effect of calving season and BCS of cows reared under KKC system showed only significant variation in mastitis and lameness inci-
idence, while those reared under FC system had a higher incidence in lameness and ketosis (Figure 3). Cows with low BCS and calved at winter, reared under KKC system had the highest incidence for assistance (n=84, 8.4%), and stillbirth (n=54, 5.4%). Though, those of the moderate BCS group complain was the most of the lameness (n=242, 24.2%) and abomasum displacement (n=18, 1.8%) at spring, and mastitis (n=50, 5%) at Summer for the high BCS group.

Conversely, the risk tended to increase mostly during spring for cows reared under the FC system. It was 4.29% (n=30) for milk fever, and 1.43% (n=10) for ketosis in the moderate BCS group; as well as 9.57% (n=67) for lameness, 2.29% (n=16) for ketosis in the high BCS group. Similarly, the rate of abortion (n=31, 4.43%) was the highest for high BCS cows calved at autumn. Further, it was noticeable that low BCS cows reared under the FC cooling system had unexplainable protection against the onset of most disorders, except for abortion (n=10, 1.43%), mastitis (n=16, 2.29%), and lameness (n=13, 1.86%) during autumn (Figure 3).

Relative risk factors of incidence for diseases in concern

Based on the importance of diseases in concern for high producing dairy cows under investigation, we decided to consider only mastitis and lameness in the multivariate Logistic regression analyses. The relative risk of occurrence of mastitis in FC system was 2.61 fold (OR) compared to the KKC one (P<0.001). This risk was maximised in low (OR=15.82 fold) and high BCS (OR=10.94 fold) compared to moderate BCS group (P<0.001). Lameness was also a high risk factor for the increase of mastitis incidence by 16.64 fold (OR) (Table 4). Season of calving

305MY, corrected 305 milk yield; DIM, days in milk; TMY, total milk yield; DMY, daily milk yield; SCC, somatic cell count; SCS, somatic cell score. *Different letters among calving seasons are significantly different (P<0.05). Values are expressed as least square means±standard error.
icconsistently affected the risk of occurrence lameness disorder. Summer and spring calving were characterised by 1.18 and 2.68 fold (OR) increase in the risk of lameness when compared to winter calving (Table 5). Moreover, the risk of lameness appeared higher in cows having 25-35 kg average milk yield (OR=1.65 fold) when compared to those having more than 35 kg. There were 2.06 fold increase in lameness incidence every other year, 5.26 fold increase due to milk fever; 20.6 fold increase due to mastitis; and 1.89 fold increase with abortion.

**Discussion**

**Cooling system and body condition score effect**

The results of this study revealed that KKC system induced satisfactory levels of milk production improvement (305TM, DIM, DMY) (P<0.05) compared to the FC system. This interaction was also detected by Ryan et al. (1992) and Correa-Calderon et al. (2005) who reported higher milk production as a result of the microclimatic modification of the KKC cow group over the FC system cows. Yet, the last authors recorded reverse findings for the average DMY (30.5±9.4 kg) in FC system and 26.6±9.8 kg for cooled one. These averages were lower than the findings listed in Tables 1 and 2.

Moreover, the advantage of the high BCS group under the KKC system over the FC one for TMY, peak milk yield, and period, is in disagreement with Flamenbaum et al. (1995), who recorded no differences (P>0.05) among cooled cows having high BCS. Furthermore, the absence of positive interaction of KKC cooling system and BCS for peak period and yield disagrees with Flamenbaum et al. (1995), who indicated significant higher peak production due to heat stress relief (cooling) by BCS level.

Cows from both cooling systems with moderate BCS superpassed the other two BCS groups for TMY, a result being recorded by Mushtaq et al. (2012). Furthermore, the significant increase of 305MY of cows having low and high BCS at calving over moderate BCS is in agreement with Bayram et al. (2012), who attributed the differences in genetic milk yield potentials to cow’s body reserve. The inconsistent effect of BCS at calving (low vs moderate vs high) on subsequent milk production traits of cows under investigation was also reported by Ruegg and Milton (1995), Markusfeld et al. (1997) and Roche et al. (2007). The non-significant variation between the two cooling systems or changes in BCS groups for SCS and counts regardless of parity stage were also indicated by Burgos et al. (2007).

### Calving season

Here, season of calving coincided with body condition and cooling system to induce significant (P<0.05) increase in milk production traits under investigation, mostly during autumn and winter. A maximum increase in

| Table 4. Relative risk for occurrence of mastitis. |
|---------------------------------|-----------------|--------------|---|
| **Cooling system**              | **OR**          | **P**        |
| FC                             | 2.61            | 1.74-3.93    | <0.001 |
| KKC                            | 1.00            | -            | -    |
| BCS groups                     |                 |              |
| Low                            | 15.82           | 9.03-27.72   | <0.001 |
| High                           | 10.94           | 6.43-18.59   | <0.001 |
| Moderate                       | 1.00            | -            | -    |
| **Parity**                     |                 |              |
| Heifers                        | 0.19            | 0.009-0.37   | <0.001 |
| Cows                           | 1.00            | -            | -    |
| **Average milk yield, kg**     |                 |              |
| <25                            | 0.73            | 0.49-1.09    | ns    |
| 25-35                          | 0.78            | 0.48-1.25    | ns    |
| >35                            | 0.42            | 0.29-0.58    | <0.001 |
| **Lameness**                   |                 |              |
| Average/year                   | 16.64           | 11.47-24.16  | <0.001 |

**Table 5. Relative risk for occurrence of lameness.**

| **Cooling system**              | **OR**          | **P**        |
|---------------------------------|-----------------|--------------|
| **Point estimate**              | **95% CI**      | **P**        |
| FC                             | 0.87            | 0.65-1.16    | ns |
| KKC                            | 1.00            | -            | -  |
| BCS groups                     |                 |              |
| Low                            | 0.05            | 0.03-0.07    | ns |
| High                           | 0.12            | 0.07-0.19    | ns |
| Moderate                       | 1.00            | -            | -  |
| **Parity**                     |                 |              |
| Heifers                        | 0.82            | 0.52-1.31    | ns |
| Cows                           | 1.00            | -            | -  |
| **Season**                     |                 |              |
| Summer                         | 1.18            | 0.89-1.55    | ns |
| Autumn                         | 0.57            | 0.33-0.99    | <0.05 |
| Spring                         | 2.68            | 2.07-3.46    | ns |
| Winter                         | 1.00            | -            | -  |
| **Average milk yield, kg**     |                 |              |
| <25                            | 0.49            | 0.37-0.65    | ns |
| 25-35                          | 1.65            | 1.24-2.19    | <0.001 |
| >35                            | 1.00            | 1.00-3.57    | <0.05 |

**Table 4. Relative risk for occurrence of mastitis.**

| **Cooling system**              | **OR**          | **P**        |
|---------------------------------|-----------------|--------------|
| **Point estimate**              | **95% CI**      | **P**        |
| FC                             | 2.61            | 1.74-3.93    | <0.001 |
| KKC                            | 1.00            | -            | -    |
| BCS groups                     |                 |              |
| Low                            | 15.82           | 9.03-27.72   | <0.001 |
| High                           | 10.94           | 6.43-18.59   | <0.001 |
| Moderate                       | 1.00            | -            | -    |
| **Parity**                     |                 |              |
| Heifers                        | 0.19            | 0.009-0.37   | <0.001 |
| Cows                           | 1.00            | -            | -    |
| **Average milk yield, kg**     |                 |              |
| <25                            | 0.73            | 0.49-1.09    | ns |
| 25-35                          | 0.78            | 0.48-1.25    | ns |
| >35                            | 0.42            | 0.29-0.58    | <0.001 |
| **Lameness**                   |                 |              |
| Average/year                   | 16.64           | 11.47-24.16  | <0.001 |

**Table 5. Relative risk for occurrence of lameness.**

| **Cooling system**              | **OR**          | **P**        |
|---------------------------------|-----------------|--------------|
| **Point estimate**              | **95% CI**      | **P**        |
| FC                             | 0.87            | 0.65-1.16    | ns |
| KKC                            | 1.00            | -            | -  |
| BCS groups                     |                 |              |
| Low                            | 0.05            | 0.03-0.07    | ns |
| High                           | 0.12            | 0.07-0.19    | ns |
| Moderate                       | 1.00            | -            | -  |
| **Parity**                     |                 |              |
| Heifers                        | 0.82            | 0.52-1.31    | ns |
| Cows                           | 1.00            | -            | -  |
| **Season**                     |                 |              |
| Summer                         | 1.18            | 0.89-1.55    | ns |
| Autumn                         | 0.57            | 0.33-0.99    | <0.05 |
| Spring                         | 2.68            | 2.07-3.46    | ns |
| Winter                         | 1.00            | -            | -  |
| **Average milk yield, kg**     |                 |              |
| <25                            | 0.49            | 0.37-0.65    | ns |
| 25-35                          | 1.65            | 1.24-2.19    | <0.001 |
| >35                            | 1.00            | 1.00-3.57    | <0.05 |

OR, odds ratio; CI, confidence interval; KKC, Korral Kool cooling; FC, fan cooling; BCS, body condition score; ns, not significant.
TMY was recorded for cows calving in winter (13616 kg) which showed also the longest peak period (28.71 days). 305MY was maximised in cows calving in autumn (12341±38.7 kg). On the contrary, summer calving cows had the least TMY (13114 kg); they were milked for 332 days but spent 55.07 days to have a peak yield (Table 3). The increase of milk production due to evaporative cooling system points to the efficiency of improving the dairy cow comfort and the maximum benefits from management programmes, genetic potentials and nutrition (Ryan et al., 1992; Armstrong, 1994; Correa et al., 1997). Moreover, the effective microclimatic modifications during summer to increase productive performance of Holstein dairy cows in hot, dry climate was also recorded by Keala (2004). However, the previous trend was not detected (P>0.05) in Brown Swiss cows, when comparing different cooling systems (Correa-Calderon et al., 2005). In addition, the interaction between BCS at calving and evaporative cooling of dairy cows throughout summer was also indicated by Flamenbaum et al. (1995).

**Parity effect**

Mature cows exceeded heifers in TMY in both moderate (13759 vs 13143 kg) and high BCS group (14040 vs 13227 kg). They also had more DIM than their corresponding heifers for all BCS groups, while moderate BCS cows showed more days in peak (28.2 days) compared to heifers (23 days) of the same group. Meanwhile, heifers had higher TMY, 305MY as well as DMY values over their contemporary mature cows. Low and heavy weight heifers also had longer peak period (40 days) and days to reach peak yield (55.9 days) than mature cows (34.5 and 48.5 days) (Figure 1). The advantages of microclimatic improvement of the cooling system on primiparous over multiparous cows for TMY, and average DMY of all BCS groups agree with the results reported by Ryan et al. (1992) and Meyer et al. (1998) for an average milk yield of primiparous cows, but disagree with Burgos et al. (2007) for overall milk production of multiparous cows. Regarding to milk yield of multiparous cows, it appeared to be more noticeable than those of the primiparous lactating cows (Meyer et al., 1998).

**Metabolic disorders and other diseases**

The large variability of metabolic disorders and other health problems recorded in the present investigation point to the important role of BCS and cooling system in affecting their magnitude and incidence. Still, the dairy herds considered in this study presented a noticeable incidence of many health problems, in spite of the cow’s high production and the satisfactory level of microclimatic modification.

**Mastitis**

Primiparous high BCS cows reared under KKC system were the most affected from mastitis (8.5%). This demonstrated effect was also reported by Heuer et al. (1999) and Roche et al. (2009). Although Gallo et al. (2002) concluded that the incidence of mastitis was lower in primiparous than multiparous cows, many researchers have not recorded any relationship between BCS and mastitis (Gearhart et al., 1990; Dyk, 1995; Ruegg and Milton, 1995; Heuer et al., 1999). Moreover, the marked variation (P<0.05) of calving season (summer, 5%) and high BCS under KKC system on the relative risk of mastitis compared to those calved at autumn (2.29%) under FC system.
disagree with Gallo et al. (2002) who did not record any significant effect of calving season on mastitis incidence.

Lameness
Moderate BCS multiparous cows kept under KKC system experienced more lameness (62.2%) than high BCS (21.57%) under FC system, due to increased mechanical stress of the heavy weight they carry (Gearhart et al., 1990). The incidence rate of lameness occurrence in the present investigation was higher than those recorded by Gallo et al. (2002). Nevertheless, Hoedemaker et al. (2009) concluded that low BCS cows at calving during early lactations (primiparous) showed higher risk to be lame than multiparous cows and high BCS cows (Mikónek et al., 2013). Furthermore, spring calving moderate BCS (KKC system - 24.2%) and high BCS (FC system - 9.57%) were characterized by much increase in the risk of lameness occurrence when compared to autumn low BCS cows (FC system - 1.8%). Gallo et al. (2002) demonstrated similar results for season of calving and the risk of lameness occurrence.

Stillbirth
Calves born dead within 24-48 h were most frequently recorded in primiparous cows having a low BCS (18%), especially in winter (5.4%), compared to mature ones because of the disproportion between cow’s pelvis and calf size. A finding agrees with Hossein-Zadeh et al. (2008). Conversely, Hansen et al. (2004) indicated that overconditioned heifers (BCS>4) were potentially susceptible to have dead calves (stillbirth) than adult cows.

Abortion
Loss of foeti (42-260 days) was greater in multiparous high producing cows having high (5.68%) and moderate (5.28%) BCS in non-evaporative environment, especially those calved at autumn (4.43%). Greater abortion incidence was noticed by Hossein-Zadeh et al. (2008) for multiparous cows, but Hossein-Zadeh and Ardalan (2011) recorded a higher rate in first and second parities. Moreover, López-Gatious et al. (2002) considered summer season the most unfavourable non-genetic factor predispose to abortion.

Assistance (calving ease)
Primiparous cows reared under the evaporative cooling system and having low BCS showed the highest incidence of assistance at calving 26.1% especially at winter 8.4%. Gaafar et al. (2011) postulated that the risk of difficulties was due to cow small body and pelvic size. Hossein-Zadeh (2013) indicated that adequate BCS at calving (moderate to high) for both multiparous and primiparous dairy cows guarantees optimization of calving ease. However, Roche et al. (2009) concluded that BCS at calving did not influence the risk of assistance (dystocia).

Displaced abomasum
Twisted abomasum from its normal position was mostly demonstrated in multiparous cows (4.4%) having moderate BCS especially in spring (1.8%). The higher incidence could be due to the high energy diet that lead to ruminal acidosis as a result of accumulation of volatile fatty acids and predispose to displaced abomasum. These findings disagree with Dyk (1995) and Gillund et al. (2001) who reported higher incidence with overconditioned cows. In addition, Hoedemaker et al. (2009) indicated it in early lactations with high BCS losses.

Milk fever
High milk producing multiparous cows having moderate BCS and calving in spring suffered from blood calcium deficiency which cannot be tolerated by body calcium balance and predispose to milk fever (7.43 and 4.29%). Yet, other studies reported high frequency of milk fever in overconditioned cows compared to moderate or thin cows (Roche et al., 2007). In addition, Dyk (1995) did not record significant relationship between BCS and milk fever.

Ketosis
There was a double fold risk of ketosis in primiparous fatty cows (high BCS) at calving (3.71%) compared to mature cows, especially in spring (2.29%). The association between overconditioned cows at calving and the higher risk of ketosis was also reported by Gillund et al. (2001). Furthermore, Ferguson (2002) concluded that fat cows eat less than thin cows and have a high negative energy balance due to increased plasma concentration of non-esterified fatty acids, a condition being associated with increased risk of ketosis.

Relative risk of disease occurrence
The first parity appeared to be a protective factor against the high incidence of both mastitis and lameness. This finding agrees with Fleischer et al. (2001), who found higher risk of mastitis in mature cows. However, others did not record any effect of parity as a risk factor for some metabolic disorders (Bartlett et al., 1986; Dohoo et al., 1984). Calving season markedly affected the risk of occurrence of lameness. Spring calving cows showed double risk (OR=2.68) more than those calved during summer (OR=1.18). This was consistent with findings of Opsomer et al. (2000) and Gallo et al. (2002), although other researchers reported no effect of calving season (Matsoukas and Fairchild, 1975). Moreover, the relative risk of lameness increased with the increase of average DMY, which was 1.65 fold of the high yield (Fleischer et al., 2001). This study did not support the association between average DMY and mastitis; still, the relative risk of mastitis was strongly associated with difference in BCS, which was 15.82 folds for low BCS and 10.04 for high BCS (Markusfeld et al., 1997; Gillund et al., 2001).

Conclusions
Dairy cows raised under evaporative cooling system showed superior production compared to those of the fan system. Season of calving coincided with BCS and cooling system to induce a significant increase in milk production traits and milk curve parameters, mostly during summer and winter. The large variability of health problem occurrence detected in higher producing dairy cows points to the important role of BCS and evaporative cooling system. Obese cows were potentially more liable to metabolic diseases. Results derived from only cow’s records need to be further investigated on each single disease under the current BCS and management strategies.

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