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Initial Body Condition Score at the Fattening Affects on the Behavioural and Physiological Responses of Holstein Friesian Steers under Heat Stress

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ABSTRACT

The objective of this study was to determine the effect of initial Body Condition Scores (BCS) on fattening performance, behavioural and physiological responses of dairy fattening steers as a thermal insulator under heat stress. Thirty six Holstein Friesian steers were allocated to three groups. For a period of 5 weeks, twice a week, the behaviour of each steer was registered for 4 h (07:00, 12:00, 18:00 and 22:00 h), recording of eating, lying, fighting, ruminating, standing, grooming and other behaviours. Steers having higher body condition score decreased feed intake ($p = 0.007$) and daily weight gain with poorer feed efficiency ($p<0.001$). The frequencies of eating, drinking, ruminating, standing, lying, grooming, fighting and other behaviours for low, moderate and high body condition scored (LBCS, MBCS and HBCS, respectively) of steers were 12.53, 11.58, 8.93 ($p<0.001$); 2.22, 3.31, 3.17 ($p = 0.428$); 11.73, 9.85, 9.20 ($p = 0.023$); 17.17, 16.07, 14.20 ($p = 0.025$); 10.77, 12.73, 17.77 ($p<0.001$); 3.41, 3.20, 1.71 ($p = 0.003$); 1.16, 2.40, 4.51 ($p<0.001$) and 1.01, 0.86, 0.51 ($p = 0.023$) min h^{-1}, respectively. The frequencies of heart rate, respiration rates, rectal temperatures and skin temperatures were 58.82, 62.40 and 63.87 pulses min^{-1} ($p<0.001$), 42.30, 44.30 and 47.10 breaths min^{-1} ($p<0.001$), 38.10, 38.30 and 38.40°C ($p = 0.246$) and 32.89, 32.92 and 32.97°C ($p = 0.432$), respectively. In conclusion, initial body condition at fattening affects on the fattening performance, behavioural and physiological responses of steers, suggesting that (LBCS) animals were more adaptive and productive in fattening under heat stress.

Key words: Body condition score, heat stress, dairy steer, fattening, behaviour, physiological responses

INTRODUCTION

Heat is a major constraint on animal productivity in the tropical belt and arid areas (Silanikove, 1992). Because a hot thermal environment is a major factor that can negatively affect production of cattle, especially having a higher genetic merit (Kadzere *et al.*, 2002; Ghorbani *et al.*, 2009) and heat stress can have negative effects on the animal welfare. Therefore, the effects of heat stress on the welfare of intensively managed cattle have been considered (Young, 1993; Jacobsen, 1996). Cattle prefer ambient temperatures of between 5 and 25°C, called "thermoneutral" zone (Roenfeldt, 1998), above which the cattle can no longer cool themselves adequately and enters heat stress (Bligh, 1973). When animals are subjected to heat stress they start physiological mechanism to get rid of extra heat. In the event of unsuccessful heat excretion, animals tend to produce lower amount of heat by depressing feed intake with changes the behavioural and physiological responses. The thicker the subcutaneous fat layer, the better the preservation of body heat but the rate of heat loss from the body is then limited by the slow conduction through the fat layer (Tarlochan and Ramesh, 2005). In order to not alleviate the fattening performance of cattle, stockman has to take some measures such as cooling and the other improvements in management of cattle (Kadzere *et al.*, 2002). Subtropical-Mediterranean zone is usually very hot and dry in summer (Strahler *et al.*, 1984) and thus, animals are exposed to heat stress for 3-5 months annually (Habeeb *et al.*, 1992; Silanikove, 1992, 2000). However, there has been limited data regarding the physiological and behavioural responses of cattle in relation to body condition scores. We do not know exactly, how the cattle having HBCS behave and change physiological responses when housed in hot climate condition. Usually, cattle increase the time spent eating in response to colder temperature, reduce the time spent eating in response to hotter temperature (Redbo *et al.*, 2001). Cattle are materials for fattening in almost all countries of the world and thus encounter a very wide range of environment. Although cattle respond climate by changing their behaviour and physiology and consequently body composition (Preston and Willis, 1974), little is known about how these responses change in intensive fattening of dairy steers with body condition score in a hot environment. Indeed, many steers kept in intensive fattening systems experience LBCS at the start of fattening. Recent developments in housing and management practice of farm animals under intensive systems reflect the increase in moral concerns about animal welfare. The welfare of an individual is its state in regard to an attempt to cope with its environment (Broom, 1986). This fact that was taken into account in this study whose aim was to investigate the effect of initial body condition scores on fattening performance, behavioural and physiological responses of dairy fattening steers as a thermal insulator under heat stress.

MATERIALS AND METHODS

The study took place during summer (from 25th July to 30th August 2006) on a commercial farm in Hatay province of Turkey. This city is located approximately at 36°North latitude and 36°East longitude in the eastern Mediterranean region where climatic condition is hot and dry in summer, warm and rainy in winter. In this location, animals are exposed to high temperatures and humidity in summer. The recorded average temperature, humidity and Total Humidity Index (THI), respectively, for this location, were 31.97±0.3°C, 63.53±1.9% and 83.4±0.9 during the experimental period. The equation used for THI (Wiersma, 1990). THI=Dry-bulb temp. (°C)+0.36×dew point temp. (°C)+41.2.

Body condition of all fattening steers was scored individually by evaluating the body of steers at the start and at the end of the experiment by the first author. Thirty six Holstein Friesian fattening steers (12-16 months of age and average 360 kg live weight) were divided into three groups of 12. The first group had low body condition scores (LBCS, BCS<2), the second group had moderate body condition scores (MBCS, BCS:2-3) and the third group had high body condition scores (HBCS, 3<BCS) at the start of the experiment. HBCS included: pins not easily distinguished, rump is well-rounded and tailhead has folds of fat. MBCS included: notches of backbone visible, ribs are rounded but easily felt, base of tailhead is sunken and the LBCS were pins easily distinguished, rump is not well rounded and tailhead has not folds of fat (Roche *et al.*, 2004). Before the experiment, animals were subjected to 15-d trial period for habituating new feeding and housing conditions. During this period, veterinary precautions for internal and external parasites were taken and animals were fed *ad libitum* with alfalfa, 1 kg maize silage and 2 kg concentrate feed. At the end of this trial period, animals were moved to individually housed barn. Initial live weights and initial body condition scores of animals were recorded in the morning of the

first day of study. Three groups of Holstein Friesian fattening steers were kept at the tethered barn for this study in fully concrete slatted floor a semi-open barn. All animals were allocated 3 m^2 space. Daily ambient temperature and humidity were recorded inside barn by using a Datalogger 175-H2 (Germany-Testo) during the experimental period. Individual feeding was applied to fattening steers *ad libitum* in concrete feeding tray. Concentrate feed and maize silage offered to steers as a mixture with free access to fresh water all day. Feed mixture included 80% concentrate feed and 20% maize silage (2550 kcal ME and 160 g crude protein per kg) (Table 1). Fattening performance such as initial body weight, initial body condition score, final body weight, final body condition score, daily weight gain, total body weight gain, total body condition score gain, feed intake and feed conversion ratio were recorded. Behavioural observations were recorded with instantaneous scan sampling (Fraser and Broom, 1990) during 1 h twice per week at 07.00, 12.00, 18.00 and 22.00 h. Each steer was observed simultaneously by the first author. The recorded activities were eating, drinking, ruminating, standing, lying, grooming, fighting and other behaviours (Table 2). Behavioural activities of the steers were recorded for all the groups from a distance of 2-3 m without disturbing the day to day managemental activities. The recorded physiological responses were heart and respiration rates, rectal and skin temperatures. Heart rates, respiration rates, rectal temperatures and skin temperatures were recorded every day at the same time (14.0 and 18.0 h) during the experimental period. Heart rates were determined by stethoscope, skin temperatures were determined by testo 825- T2 laser thermometer and rectal temperatures also were determined by body thermometer. Respiration rates also were determined on the observation day by counting

Table 1: Feed composition and chemical analysis of the experiment diet

Ingredients	%
Maize silage (240 DM, 1852 ME, 78 CP, 186 CF)	20
Barley (890 DM, 3120 ME, 110 CP, 52 CF)	20
Maize (890 DM, 3240 ME, 90 CP, 26 CF)	6
Wheat (890 DM, 3110 ME, 115CP, 26 CF)	9
Wheat bran (890 DM, 2500 ME, 157 CP, 96 CF)	17
Molasses (beet) (780 DM, 2890 ME, 85 CP)	3
Cotton seed meal (920 DM, 2580 ME, 330 CP, 215 CF)	17
Sunflower meal (900 DM, 2180 ME, 360 CP, 56 CF)	6
Mineral and vitamin premix (Ca: 180 g, Na: 110 g, P: 70 g, Mg: 30 g)	2
Chemical composition	Concentration
Dry matter (g kg^{-1})	745
ME (kcal kg^{-1})	2550
Crude protein (g kg^{-1})	160
Crude ash (g kg^{-1})	108

Table 2: Descriptions of recorded behaviours

Eating	Chewing of feed mixture
Drinking	Lowering the muzzle into the water, keeping the nostrils above water, and sucking water into the mouth
Ruminating	Ruminating when standing and lying position
Standing	Standing without any movement or behaviour
Lying	Lying without any movement or behaviour
Grooming	Grooming own or partner bodies and feeding tray
Fighting	Fighting butting and pushing on partners
Others	Defecation, urination and sexual behaviours

breaths taken in 15 sec intervals. Data were analysed by in a "Repeated Measures General Linear Model" with the main effects of steer groups (low, moderate and high BCS; LBCS, MBCS and HBCS, respectively). When a significant difference was determined between body condition score groups, DUNCAN test was used to accurately determine which treatments were significantly different (SPSS for Windows, release 13.00).

RESULTS

Body condition scores, daily weight gain, feed intake, feed conversion ratio; behavioural activities (min h^{-1}) and physiological responses (counts/min) during the experimental period (35 days) are presented in Table 3 and 4.

Fattening performance: Final body condition score ($p<0.001$), daily weight gain ($p<0.001$), feed intake ($p = 0.007$), feed conversion ratio and body condition score gain ($p<0.001$) were affected significantly by initial body condition scores of fattening steers (Table 3).

As given in the material and method section, groups were allocated by initial body condition scores of the animals. When looked daily weight gain, feed conversation ratio and body condition score in Table 3, as expected, the heavier initial body condition score caused the lesser daily weight gain, feed intake, feed conversion ratio and body condition score gain.

Table 3: Fattening performances (Means±SED) of steers groups in different body condition scores

	Groups				
Performance traits	LBCS	MBCS	HBCS	SED	p
Initial body condition score	1.65±0.07[a]	2.80±0.09[b]	3.70±0.03[c]	0.104	<0.001
Final body condition score	3.21±0.08[a]	3.34±0.06[b]	3.81±0.05[c]	0.083	<0.001
Feed intake (kg day^{-1})	11.79±0.6[a]	10.73±1.1[b]	9.89±0.8[b]	0.208	0.007
Daily weight gain (g, 1-35 days)	1333±0.3[a]	1098±0.5[b]	957±0.7[b]	0.426	<0.001
Feed conversion ratio (1-35 days)	8.85±0.23[a]	9.77±0.18[b]	10.33±0.27[b]	0.184	<0.001
Body condition score gain (1-35 days)	1.56±0.09[a]	0.54±0.08[b]	0.11±0.04[c]	0.957	<0.001

LBCS: Low BCS, MBCS: Moderate BCS, HBCS: High BCS

Table 4: Behavioural and physiological responses (Means±SED) of steers groups during 1 h

	Groups				
Behaviours (min h^{-1})	LBCS	MBCS	HBCS	SED	p
Eating	12.53±0.98[a]	11.58±0.76[b]	8.93±0.85[c]	0.100	<0.001
Drinking	2.22±0.66	3.31±0.51	3.17±0.57	0.067	0.428
Ruminating	11.73±1.26[a]	9.85±0.98[b]	9.20±1.09[b]	0.128	0.023
Standing	17.17±1.39[a]	16.07±1.07[b]	14.20±1.20[c]	0.141	0.025
Lying	10.77±1.60[a]	12.73±1.25[b]	17.77±1.40[c]	0.063	<0.001
Grooming	3.41±0.09[a]	3.20±0.12[a]	1.71±0.55[b]	0.079	0.003
Fighting	1.16±0.17[a]	2.40±0.15[b]	4.51±0.13[c]	0.078	<0.001
Others	1.01±0.10[a]	0.86±0.12[b]	0.51±0.09[b]	0.073	0.023
Physiological responses					
Heart rate (pulses min^{-1})	58.82±0.74[a]	62.40±0.42[b]	63.87±0.23[c]	0.462	<0.001
Respiration rate (breaths min^{-1})	42.30±0.33[a]	44.30±0.51[b]	47.10±0.44[c]	0.420	<0.001
Rectal temperature (°C)	38.10±0.11	38.30±0.11	38.40±0.04	0.122	0.246
Skin temperature (°C)	32.89±0.05	32.92±0.05	32.97±0.05	0.026	0.432

[a,b,c]Different between groups within the rows. LBCS: Low BCS, MBCS: Moderate BCS, HBCS: High BCS

Behavioural responses: The LBCS steers showed 0.95 and 3.6 min h^{-1} more eating activity compared to the MBCS and the HBCS steers respectively (1-35 d) ($p<0.001$) (Table 4). Drinking activity was not different between body condition score groups ($p = 0.428$). LBCS tended to show less drinking activity than those of MBCS and the HBCS steers, 2.22, 3.31 and 3.17 min h^{-1} in LBCS, MBCS and HBCS animals, respectively (Table 4). Ruminating behaviour of the all animals decreased by week throughout the experimental period. The lowest body condition scored steers showed the highest ruminating activity while the HBCS steers showed the lowest ruminating activity ($p = 0.023$). LBCS steers showed 1.88 and 2.53 min h^{-1} more ruminating behaviour than those of MBCS and HBCS animals, respectively (Table 4). All animals decreased standing behaviour thorughout experimental period. Low condition scored animals stood more frequently than the HBCS animals ($p = 0.033$). The time spent for standing behaviour in low condition scored steers were 1.1 and 2.97 min h^{-1} higher than those of the respective moderate and high condition scored steeers (Table 4). When steers were fattening, they were lying more during from the first week to fifth week of experimental period. High condition scored steers showed more lying behaviour compared to the LBCS and MBCS steers 7.00 and 5.04 min h^{-1} more than low and moderate condition scored steers, respectively ($p<0.001$) (Table 4). LBCS steers showed higher rate of grooming behaviour ($p = 0.003$). This behaviour was 0.21 min h^{-1} in moderate condition scored steers and 1.70 (min h^{-1}) in HBCS steers (Table 4). As an aggressive behaviour, fighting was increased throughout experimental period from starting to the end. HBCS animals fought more between each other than LBCS animals. HBCS animals fought 3.35 min more than LBCS animals and 2.11 min h^{-1} more than MBCS animals ($p<0.001$) (Table 4). Other behaviours as defecation, urination and sexual behaviours decreased throughout experimental period in all steers.

Physiological responses: Heart rate (pulses min^{-1}) was increased in steers through the experimental period from starting to end. Heart rate was the highest in HBCS steers and the lowest in LBCS steers ($p<0.001$). HBCS animals showed heart rates of 5.05 and 1.47 (pulses min^{-1}) more than those of the respective LBCS steers and MBCS steers (Table 4). Respiration rate (breaths min^{-1}) increased by week throughout experimental period. Respiration rate was found the highest in HBCS animals, followed by the MBCS and the LBCS steers ($p<0.001$). HBCS steers respirate 4.80 breaths more than the MBCS steers and 2.80 breaths per min more than the LBCS steers (Table 4). Rectal and skin temperatures (°C) were not different all body condition score groups ($p>0.05$) but rectal temperature was high in all animals. The lowest body condition scored steers had the lowest rectal and body skin temperatures (Table 4).

DISCUSSION

Fattening performance and behavioural responses: Feeding behaviour is affected by climate. In general, feed intake in a controlled climate laboratory was depressed by increasing environmental temperatures (Pearce and Moir, 1964). In the present study, HBCS animals consumed less food or showed less eating behaviour most probably, in order to control their body temperature in balance (Table 4). As expected LBCS steers total body condition and body weight gain, daily weight gain, feed intake and feed conversion ratios were higher than those of MBCS and HBCS ones. This can be explained by compensatory growth that steers poor in body weight and size, when given opportunity, eat higher amount of food and gain faster in comparison to better animals with respect to body weight and size. Although, the LBCS steers ate more food than the other groups of steers at the end of the experimental period, their food consumptions were reduced during the experimental period. This may be due to the increased subcutaneous and internal fat by age and higher body condition. Consequently, fat tissues might have prevented the produced heat to be dissipated or eliminated by skin. Therefore, animals were under heat stress. In the present study, due to the average temperature-humidity index was 83 during the experimental period and animals were extremely distressed. Temperature-humidity index values of 70 or less are considered comfortable, 75-78 stressful and values greater than cause extreme distress with cattle being unable to maintain thermoregulatory mechanism or normal body temperatures (Kadzere *et al.*, 2002). Heat stress causes the rostral cooling center of the hypothalamus to stimulate the medial satiety center which inhibits the lateral appetite center, resulting in reduced dietary intake and consequently lower production (Silanikove, 2000). When the animals were under the heat stress, their physiological responses such as rectal temperature, respiration and heart rate were higher than those under the normal conditions. The rectal temperature, heart and respiration rates were higher in the HBCS steers than those of other groups of steers. Rectal temperature is an indicator of thermal balance and may be used to assess the adversity of thermal environment which can affect the growth of cattle (Johnson, 1980). Thermoneutral zone (TNZ) can be understood as the zone of minimal heat production at normal rectal temperature. TNZ was related to heat and water balances of animals. Within the TNZ, minimal physiological costs and maximum productivity are normally achieved Generally, the TNZ range (from Lower Critical Temperature (LCT) to Upper Critical Temperature (UCT) depends on age, species, breed, feed intake, diet composition, previous state of temperature acclimation or acclimatization, production, specific housing and pen conditions, tissue insulation (fat, skin), external insulation (coat) and behaviour of an animal (Johnson, 1987). Drinking behaviour of cattle is very much dependent on feeding pattern, ambient temperature, water quality and availability (Albright and Arave, 1997). Cattle in a thermoneutral environment drink during daylight hours, with peaks of activity at sunrise and sunset but when heat-stressed shift drinking frequency to afternoon, evening and some into the night (Ray and Roubicek, 1971; Arnold and Dudzinski, 1978; Gonyou and Stricklin, 1984). According to current behavioural observation, MBCS and HBCS steers tended to show more drinking activity compared to LBCS ones. This behavioural response was more likely because of summer stress rather than food intake. In addition to water loss from evaporation during thermoregulation of body temperature by cattle exposed to hot temperatures (Bray *et al.*, 1992). Heat stress in HBCS steers results in a dramatic reduction in rumination behaviour. It is likely that HBCS steers ruminated less compared to other groups steers. The underlying mechanism in lower percentage of ruminating behaviour can be explained as the HBCS steers tackled the adverse effect of heat stress by ruminating less so that they can produce lower rate of metabolic heat. Less rumination may be the mechanism which enables HBCS steers to reduce the adverse effect of heat stress (Kadzere *et al.*, 2002). More standing behaviour in LBCS steers indicates that they showed more eating behaviour rather than subjecting heat stress. On the other hand, fatty steers preferred to lie on the concrete slatted floor with urinated and excreted in order to dissipate their body heat. This was illustrated by Table 4 that low condition scored animals decreased standing behaviour by week but increased lying down behaviour. Most likely, skin plus subcutaneous fat insulation may cause heat stress. For this reason stressed animals tried to eliminate this by increasing lying down behaviour on concrete slatted floor with urinated and defecated (Johnson, 1987). Rest is "vital to the animal in its integration and mediation with its environment" (Fraser, 1983). Resting time by cattle is mostly spent lying (Arnold, 1984) and it will be noted later a large part of the day is spent in such behaviour (Bayer, 1990). Lying time depends somewhat on type of housing, comfort of stall or lying out area, type of diet and climatic factors (Dechamps *et al.*, 1989). Higher body conditioned steers were more likely tried to show thermoregulatory behaviour by conducting energy to fully concrete slatted floor by lying on because the fattening steers were kept on shade protected from the sunshine. Due to the insulation of subcutaneous and internal fat, MBCS and HBCS steers were not able to dissipate of heat. One good indicator of general health or thriftiness is the behaviour of cattle toward care of their own (self-grooming) and haircoat of herdmates (allo-grooming) through licking, rubbing and grooming (Albright and Arave, 1997). In the current study, HBCS animals did not show grooming behaviour as much as the LBCS animals. This might be a sign of distress of fattening steers having higher body condition score (Table 4). Fighting is aggressive behaviour which social interactions between animals often involve some degree of conflict. This may be related to obtaining food, sexual mates, or preferred rest areas. Other sources of conflict arise as a result of a tendency of animals to protect a territory (Hart, 1985). In the current study, fattening steers having higher body condition score showed more aggressive behaviour, suggesting that this may be a sign of distress against climate conditions and a higher body fat ratio (Table 4). MBCS and HBCS steers increased fighting behaviour. This might be due to be in need of more resting area not to contact between each other's body surface for catching from heat loading and be lying down to dissipate heat. This result of course, should be investigated further by analysing stress hormones in blood in order to explain the underlying mechanism of the aggressive behaviour. Urinating, defecation and sexual behaviour were higher in low condition scored steers. On the other hand, HBCS animals showed these behaviours less, perhaps, in order not to loss water from their body to regulate body temperature. Temperature, humidity and animal density will affect defecation in cattle (Phillips, 1993).

Physiological responses: Rectal temperature is an indicator of thermal balance and may be used to assess the adversity of the thermal environment which can affect the growth (Johnson, 1980; Hahn, 1999; Hansen and Arechiga, 1999; West, 1999). A rise of 1°C or less in rectal temperature is enough to reduce performance in most livestock species (McDowell *et al.*, 1976; Shebaita and El-Banna, 1982) which makes body temperature a sensitive indicator of physiological response to heat stress in the cow because it is nearly constant under normal conditions. Responses of the cattle to temperatures above TNZ are varied. These include raised respiration rates and rectal temperature (Omar *et al.*, 1996), panting, drooling, reduced heart rates and profuse sweating (Blazquez *et al.*, 1994), decreased feed intake (NRC, 1989). High ambient temperatures induce physiological adjustments, including increased respiration rate (Coppock *et al.*, 1982). Berman *et al.* (1985) found that the respiratory frequency started rising above 50-60 breaths min^{-1} at ambient temperatures higher than 25°C. Physiological parameters showed that climate conditions increased heart rate, respiration rate and rectal temperature in higher body condition scored animals (Table 4). Animals regulate their body temperature by conduction, convection, radiation, evaporation of water and through expired air. Heat dissipation is shifted from radiation and convection at lower environmental temperatures to vaporization at higher temperatures. Heat lost by the skin is dependent partly on the temperature gradient between skin and air and solid objects (Silanikove, 2000). The importance of water as a medium for ridding the body of excess heat through sweating and respiration greatly increases as the ambient temperature rises (Richards, 1985).

CONCLUSIONS

Heat stress exerts an influence on fattening productivity through an interaction between the animal's behavioural and physiological changes. To optimize the efficiency of using body fat in minimizing maintenance energy requirements and maximize the economic efficiency of fattening. Feeding and housing managements systems could be devised that are climate and animal type specific and that would establish optimum body condition during appropriate periods of the fattening period. Therefore, the lower body condition scored animals should be used for fattening materials since higher environmental temperature and higher body fat, both together, will decrease feed efficiency. The present study suggests that fattening should not be done Subtropical-Mediterranean zone in summer, especially for the steers having HBCS in last period of fattening.

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