Archiv Tierzucht 56 (2013) 4, 28-41

Open Access

Original study

Effects of air temperature and humidity on average daily gain in feedlot cattle of different genotypes

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Abstract

The purpose of this study was to observe Holstein, Brown Swiss, Simmental and cross breed Anatolian Black genotypes fattened in feedlot regarding their ability to tolerate temperature and humidity and to compare Temperature Humidity Index types under climatic conditions of Şanlıurfa province in Turkey. Data obtained from a commercial farm composed of 70 594 test day records of 11 117 cattle (6 513 Holstein, 3 546 Brown Swiss, 838 Simmental and 220 Anatolian Black Crosses). Meteorological data were provided from nearest weather station located 9.04 km away from feedlot area. THI values were calculated by using daily maximum, minimum and average air temperature and, humidity values according to three different combinations for each animal. Analysis were based on such a model that includes effects of year, sex, age, season, days on feed, beginning stage of fattening and several types of THI. Results showed that, Simmental and Anatolian Black genotypes were slightly more tolerant to heat stress compared to Holstein and Brown Swiss. In addition, Anatolian Black genotype was more sensitive to cold stress when compared to other genotypes. Different breakpoint values for stress and comfort zone intervals were obtained when different combinations of temperature and humidity variable (maximum or minimum) were used in THI formula.

After 72 THI values, which is reported in literature as the threshold for heat stress in cattle, average daily gain loses were observed. But, this is only detected when maximum temperature and minimum humidity variable is used. Results from this study indicated that trends of temperature and humidity in the air were important factors for THI calculation types when data from the weather stations were used. Because, this gives useful information about, which combination of temperature and humidity values (maximum, minimum or average) best reflect the heat stress for genotype.

Archiv Tierzucht 56 (2013) 4, 28-41
doi: 10.7482/0003-9438-56-004

Received: 11 September 2011
Accepted: 22 August 2013
Online: 8 February 2013

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Keywords: feedlots, cattle, air temperatures, humidity, heat stress

Abbreviations: AB: Anatolian Black, ABC: Anatolian Black Crosses, ADG: average daily gain, BS: Brown Swiss, H: Holstein, LSM: least square means, ME: metabolisable energy, MSE: mean square error, R^2: coefficient of determination, S: Simmental, SE: standard error, THI: temperature humidity index, THI-1: maximum temperature and minimum humidity, THI-2: average temperature and average humidity, THI-3: maximum temperature and maximum humidity

Introduction

Among the factors that affect the performance, well-being and health of animals are also meteorological factors. Most important climatological factors affecting animal health are high temperature and relative humidity during hot periods and wind-chilling factor during cold periods (Brouček *et al.* 2006). Summer conditions raging above normal ambient temperature, relative humidity and solar radiation along with low wind speed can increase animal heat load, resulting in reduced performance, decreased animal comfort and death (Mader *et al.* 2006). Considering the increase of global warming, this situation apparently would impose a more serious problem for livestock. Similar to other farm animals, when feedlot cattle are exposed to heat stress, a heat loss mechanism becomes activated resulting in increased aspiration and sweating. High relative humidity reduces the evaporation and makes dissipation of body heat more difficult when the environmental temperature is close to the cow's body temperature (West 1994). Vaporisation from the respiratory tract and the outer body surface both are affected directly by the temperature and relative humidity of the air (Kibler & Brody 1953, West 1994). Metabolic activation related in stress condition causes decreased production and hence economic losses, besides increased energy requirement. According to NRC (2001); increased panting score may also increase energy requirement by 7-25 %. Also, productivity curve, relative to one unaffected by heat stress is similar to the relationship shown in Figure 1 (Ravagnolo *et al.* 2000).

Ravagnolo *et al.* (2000) reported that for test-day yield, depression caused by heat is a function of the top, average, or lowest temperatures and humidity during 24 h preceding recording; the management style, including the availability of antiheat stress measures (e.g., sprinklers, shading, and fans); the duration of the current heat stress; and the duration of previous heat stresses.

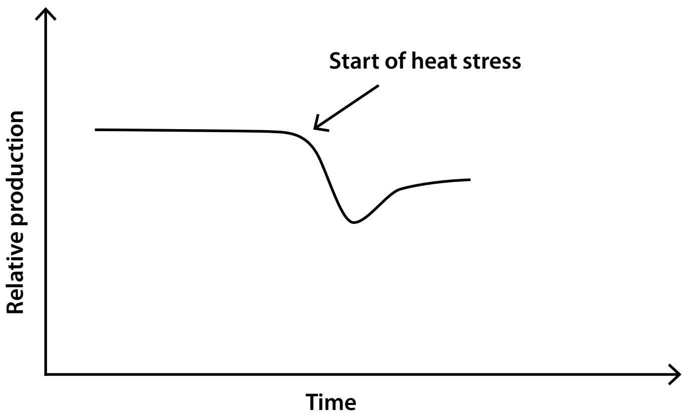

Figure 1
Production curve of animals exposed to heat stress relative to unaffected production curves (Ravagnolo *et al.*, 2000).

There are many approaches from modest to complex methods to quantify heat stress, such as THI (Igono *et al.* 1992, Linvill *et al.* 1992, Ravagnolo *et al.* 2000, Aguilar *et al.* 2009). THI is used instead of the temperature itself (Ingram 1965, Šleger & Neuberger 2006) and various THI have been developed by using dry bulb temperature, in combination with wet bulb temperature, relative humidity, or dew point (Buffington *et al.* 1981, Roseler *et al.* 1997, Gaughan *et al.* 2008). THI can be calculated by coupling temperature and humidity into one value as shown in following equation (Mader *et al.* 2006):

$$THI = 0.8 \times t_a + \frac{RH}{100} \times (t_a - 14.3) + 46.3 \qquad (1)$$

where *THI* is the temperature humidity index, t_a is the ambient temperature in °C and *RH* is the relative humidity, %.

According to this formula, heat stress starts at a THI of 72, which corresponds to 22 °C at 100 % humidity, 25 °C at 50 % humidity, or 28 °C at 20 % humidity. In addition, knowing THI alone is beneficial in determining the impact of heat stress for feedlot cattle (Mader *et al.* 2006).

In H cows, after intensive selection programs are carried out mostly in temperate climates worldwide, a reduced heat tolerance appeared due to productivity and heat tolerance antagonism (Johnson *et al.* 1962).

AB is one of the native cattle breeds of Turkey and well known with its rusticity, disease resistance, tolerance to restricted feeding, poor care and relatively adverse climate conditions. But there is no reliable information about heat stress effect in AB cattle or its crossbreeds with different genotypes such as H, S and BS. Şanlıurfa province is located in southeastern region and is considered as one of the hottest provinces of Turkey. In this region, weather is hot and dry from July to October when temperatures can reach up to 47 °C, and an average of 410 mm of precipitation occurs in a year and the relative humidity averages about 49 % (Şimşek *et al.* 2005).

For dairy cows a model that accounts for heat stress using test-day records and weather data obtained from nearest public weather stations proposed by Ravagnolo & Misztal (2000). They have also reported that maximum daily air temperature and minimum daily humidity seem to be the most critical variables to quantify heat stress. In practice, it can be useful to know the effects of temperature and humidity as partial or together. Just as West (2003) reported that several combinations of temperature, relative humidity and radiant energy impact heat load in the cow. Due to differences of genotypes, cattle may have different reactions to increases of the temperature when the humidity decreases; conversely when temperature decreases and humidity increases or when both of two variables increase. Just as, Hammond *et al.* (1998), reported that heat tolerance of F_1 crosses of tropically adapted breeds (Tuli, Senepol & Brahman) with a temperate breed (Angus) is similar to heat tolerance displayed by purebred tropical breeds (Senepol & Brahman). On the other hand, Gaughan *et al.* (1999) have reported that Hereford × Boran & Hereford × Tuli are similar to Hereford × Brahman and intermediate to Hereford & Brahman genotypes in maintaining homeostasis when exposed to high heat load. There are many aspects of genetics that influence the response to heat stress, and variation among breeds is large (West 2003). The best way to prevent the deterioration of heat tolerance would be a routine evaluation that considers heat stress and subsequent selection for best performance under heat stress (Ravagnolo *et al.* 2000). Detection of how each genotype is influenced by change of temperature and humidity variables (maximum or minimum) can provide useful information for genetic evaluation. Genetic variation in heat loss via tissue conductance, nonevaporative heat loss and evaporative heat loss (Finch 1985) confirmed this.

Principal aims of this study were to calculate temperature and humidity effect on ADG taking into account test-days; to compare THI method using average, minimum or maximum temperature and humidity for different genotypes such as H, BS, S and ABC kept in feedlot under climatic conditions of Şanlıurfa.

Materials and methods

Data used in this study were obtained from a commercial feedlot which is one of the biggest farms in Turkey located in Şanlıurfa province (37° 08' 48'' north latitude and 39° 05' 40'' east longitude). Total capacity of feedlot was about 13 000 steers. Across all feedlots stocking density varied from 9 to 9.9 m^2/animal and in feedlot all animals are within shadows. The shades which contain canopy material with 0.50 mm white colour trapezoidal sheet were about 4.20-8.00 m of height and are available for all animals. During hottest days a hose-spraying shower system was provided for animals. H, BS, S and ABC genotypes were used as fattening material. Castration process has not been applied on animals. Animals were weighed every 33 days on average with ± 5 kg sensitivity. Cattles had *ad libitum* access to feed (~13.1 % crude proteins and 2 660 kcal/kg ME) and water. Feedlot ration was composed of corn, barley, soybean-meal, wheat bran, molasses, cottonseed-meal, corn bran, sunflower seed-meal, wheat straw, corn and wheat silage, limestone, vitamin-minerals premix and salt. Energy and crude protein levels were fixed throughout the fattening.

Data set comprised of 108 334 test day records of 12 504 cattle. For each animal, it was required that at least 4 test-day records were present in order to be included in the analysis. ADGs, g for each animal calculated are shown in following equation:

$$ADG_n = \frac{TD_n - TD_n - 1}{t_n - t_n - 1} \times 1\,000 \qquad (2)$$

where ADG_n is the average daily gain on *n*-th interval, g, TD_n is the *n*-th test day record, kg and *t* is the time, day. Records with ADG <300 g or ADG >1 800 g (represent anomaly record due to sickness and other feeding problems or weighing and saving data errors) are eliminated from the data. Thus, production data set consisted 70 594 test day records for 11 117 cattle (6 513 H, 3 546 BS, 838 S and 220 ABC). Distributions of records by genotype are presented in Table 1.

Table 1
Production data by genotype

Genotype	Number of animals, n	Number of observation, n	ADG, g ± SE
Holstein	6 513	38 371	1 238 ± 1.4
Brown Swiss	3 546	25 111	1 222 ± 1.7
Simmental	838	5 666	1 263 ± 3.6
Anatolian Black Cross	220	1 446	1 199 ± 7.2
Total	11 117	70 594	-

Weather data used in this research were provided from nearest weather station to the feedlot location at Drupe and Pome Fruits R&D and Gardening unit within the Faculty of Agriculture of Harran University Campus, Turkey. Point to point distance between the meteorological station and feedlot is 9.04 km. Air temperature (maximum and minimum) and relative humidity, % have been measured and recorded daily in this weather station since 2005.

In Table 2 have been presented a summary of the heat and humidity meteorological data of the years 2008 and 2009. Daily maximum temperature and minimum humidity, daily maximum temperature and maximum humidity and finally daily average temperature and average humidity values have been implemented in the expression proposed by Mader *et al.* (2006) (Equation 1).

Table 2
Mean weather data calculated from 2008-2009 years in Sanliurfa province of Turkey

Item	Maximum	Average	Minimum
Daily Temperature, °C	24.66	18.24	11.82
Daily Humidity, %	65.21	46.56	27.90

Animals existed in different times in the farm between 2008 and 2009 years. So, they were weighed on different times but once in every 33 days. Because of these test day differences and those test day yields reflected the effect of the climatically conditions of previous period (Ravagnolo *et al.* 2000), the mean values of maximum temperature, minimum temperature, maximum humidity, minimum humidity, average temperature and average humidity of the 33-day period were calculated for each animal. As mentioned earlier, in order to detect which combination of temperature and humidity values (maximum, minimum or average) best reflect the heat stress for genotype, THI-1, THI-2 and THI-3 types were calculated for 33-day period (test day interval) for each animal using Equation 1. Accordingly, for THI-1; mean maximum temperature and mean minimum humidity values, for THI-2; mean average temperature and mean average humidity values and finally for THI-3; mean maximum temperature and mean maximum humidity values were used. As a result, as much as number of total test day records, other words for each THI types 70 594 values were calculated separately.

In order to calculate temperature-humidity effect on ADG and to obtain LSM for each THI types Equation 3 was used. For each genotype (H, BS, S and ABC) and each THI type (THI-1, THI-2 and THI-3) separate analysis were performed.

$$y_{ijklmno} = \mu + yr_i + s_j + a_k + m_l + DOF_m + THI_n + bW_{ijklmno} + e_{ijklmno} \quad (3)$$

where $y_{ijklmno}$ is the test day yield for year effect yr_i 2008 through 2009, the sex effect s_j 1 through 2, the age effect a_k≤3, 4-6, 7-9, 10-12, 13-15, 16-18, 19-21, 22-24 and >24 months, the month effect m_l 1 through 12, 1 through 15, the days on feed effect DOF_m (days on feed: in order to take into account test day effect in the model; the turn of animals weight – first, second or fifth – has been considered an effect and is named DOF) 1 through 15, the THI_n for THI-1: <60, 63, 66, …, 78 and >78, for THI-2: <54, 57, 60, … , 75 and 78 and for THI-3: <63, 66, 69, … , 87 and >87, μ is the over all mean, *W* is the weight at the beginning to fattening, *b* is the linear regression coefficient, *e* is the random residual error. All analyses were performed with the GLM procedure of SAS program package 6.12 (SAS Institute Inc., Cary, NC, USA).

Results

While in all analysis, all fixed effects have been found significant (P<0.01), and coefficient of determinations (R^2) have taken small values as given in Table 3. In addition, R^2 for THI-1, THI-2 and THI-3 and Root MSE values with all three THI types in mind were close to each other. On the other hand, when R^2 and Root MSE's of THI-1, THI-2 and THI-3 on the basis of genotypes are compared, ABC genotype acquires the highest R^2 value. When R^2 values are taken into consideration, it's concluded that only a small portion of the average daily gain for all genotypes is affected by heat and humidity changes. These results were similar to ones reported by Ravagnolo *et al.* (2000).

Table 3
Coefficient of determination and root mean square error (Root MSE) for different temperature-humidity indexes by genotype

	Holstein		Brown Swiss		Simmental		Anatolian Black Cross	
Item	R^2	Root MSE	R^2	Root MSE	R^2	Root MSE	R^2	Root MSE
THI-1a	0.053	271.21	0.106	254.23	0.137	259.09	0.284	264.52
THI-2b	0.055	270.93	0.107	254.15	0.137	259.08	0.290	263.59
THI-3c	0.054	271.10	0.108	254.01	0.139	258.83	0.289	263.86

Figure 5 shows the LSM for test day average daily gain, when using maximum temperature and minimum humidity (THI-1) in the Equation 3. For all genotypes, daily average gain values have increased until the THI-1 index's value of 63 (start point of comfort zone). For H, BS and S genotypes the LSM of increases average daily gains of the named genotypes are calculated to be 42, 74.8 and 81.7 g respectively (Table 4) and are found to be statistically significant (P<0.01). However, the daily average gain for genotype ABC as THI-1 increases from <60 to 63 are insignificant. In addition, on periods when THI-1 was lower than 63, (between days 1-76 and 317-365) air temperature was 0-20 °C, humidity ranged between 18-90 % and the average is around 50 % (Figure 2).

Table 4
LSM and SE of average daily gains for THI-1, THI-2 and THI-3 by genotype

	Holstein (n=38 371)	Brown Swiss (n=25 111)	Simmental (n=5 666)	Anatolian Black Cross (n=1 446)
THI-1	LSM ± SE	LSM ± SE	LSM ± SE	LSM ± SE
<60	1 211.6 ± 27.61^{ab}	1 164.8 ± 19.56^{a}	1 179.6 ± 29.24^{a}	1 229.6 ± 42.74^{a}
63	1 253.5 ± 28.36^{c}	1 239.6 ± 21.13^{b}	1 261.3 ± 34.21^{b}	1 322.8 ± 52.89^{abcd}
66	1 270.0 ± 27.78^{c}	1 219.4 ± 20.04^{b}	1 238.9 ± 31.02^{bc}	1 356.5 ± 48.95^{b}
69	1 252.0 ± 30.80^{cdfb}	1 219.7 ± 24.79^{b}	1 214.9 ± 54.44^{abcd}	1 223.9 ± 76.80^{abcd}
72	1 258.8 ± 27.77^{c}	1 224.6 ± 19.86^{b}	1 232.7 ± 30.08^{bc}	1 347.2 ± 47.09^{abc}
75	1 170.0 ± 28.66^{e}	1 140.9 ± 23.48^{a}	1 132.9 ± 42.15^{acd}	1 195.4 ± 80.98^{abcd}
78	1 199.1 ± 27.64^{ae}	1 147.7 ± 19.64^{a}	1 148.1 ± 29.75^{ad}	1 239.3 ± 42.76^{d}
>78	1 211.1 ± 27.70^{ab}	1 212.0 ± 19.99^{b}	1 230.4 ± 30.37^{bc}	1 261.8 ± 44.81^{abcd}
THI-2				
<54	1 213.3 ± 27.59^{af}	1 166.8 ± 19.54^{ag}	1 188.1 ± 29.29^{a}	1 229.3 ± 42.49^{a}
57	1 289.6 ± 27.94^{b}	1 269.5 ± 20.64^{b}	1 282.3 ± 32.64^{b}	1 412.0 ± 51.13^{b}
60	1 259.9 ± 28.06^{c}	1 201.8 ± 20.38^{e}	1 244.6 ± 32.32^{bc}	1 305.4 ± 54.07^{ab}
63	1 274.9 ± 31.18^{bcdg}	1 212.6 ± 25.84^{abef}	1 184.7 ± 70.04^{ba}	1 280.5 ± 83.83^{ab}
66	1 261.8 ± 27.76^{cd}	1 225.2 ± 19.89^{ce}	1 237.4 ± 30.23^{bcd}	1 352.7 ± 47.11^{bc}
69	1 172.9 ± 28.63^{e}	1 144.8 ± 24.18^{afg}	1 136.2 ± 43.91^{ace}	1 180.2 ± 86.72^{ab}
72	1 204.7 ± 27.66^{f}	1 156.0 ± 19.69^{g}	1 162.7 ± 30.17^{a}	1 240.4 ± 43.36^{a}
75	1 188.7 ± 27.80^{ef}	1 161.6 ± 20.40^{ahg}	1 182.4 ± 31.59^{ac}	1 289.7 ± 49.05^{ab}
78	1 227.1 ± 27.92^{ag}	1 218.3 ± 20.53^{de}	1 250.5 ± 33.13^{bce}	1 232.3 ± 48.84^{ac}
THI-3				
<63	1 208.8 ± 27.59^{ai}	1 163.7 ± 19.52^{a}	1 180.0 ± 29.23^{afh}	1 221.3 ± 42.52^{a}
66	1 279.4 ± 28.01^{b}	1 253.8 ± 20.63^{b}	1 283.9 ± 32.32^{bc}	1 348.1 ± 49.80^{b}
69	1 247.4 ± 27.87^{cdef}	1 206.5 ± 20.13^{c}	1 216.2 ± 31.64^{acg}	1 326.7 ± 51.09^{ab}
72	1 223.9 ± 37.67^{abefgh}	1 227.1 ± 26.27^{bcd}	1 216.0 ± 62.11^{bdgf}	1 095.7 ± 91.70^{ab}
75	1 270.5 ± 28.00^{bef}	1 214.6 ± 20.69^{cde}	1 212.9 ± 32.55^{bdgh}	1 368.7 ± 50.33^{bc}
78	1 226.8 ± 27.93^{adh}	1 224.6 ± 20.21^{bcdefg}	1 246.2 ± 32.16^{bdeg}	1 296.6 ± 52.68^{ab}
81	1 212.9 ± 29.09^{chgi}	1 154.2 ± 23.37^{ag}	1 154.9 ± 42.75^{fg}	1 229.6 ± 92.25^{ab}
84	1 186.4 ± 27.60^{g}	1 139.5 ± 19.64^{g}	1 141.8 ± 29.72^{f}	1 220.8 ± 42.96^{ad}
87	1 219.3 ± 28.06^{hi}	1 220.1 ± 20.77^{bcdeh}	1 223.1 ± 32.84^{agb}	1 279.5 ± 47.40^{ab}
>87	1 221.9 ± 27.85^{hi}	1 207.1 ± 20.32^{cdeh}	1 237.2 ± 32.30^{agb}	1 222.8 ± 49.95^{ab}

^{a,b,c,d,e,f,g,h} Means with not the same letter are significantly different (P<0.01).

From 63 THI-1 values to 72 which has been reported to be the end of stress-free zone for feedlot and dairy cattle (Mader *et al.* 1999, Ravagnolo *et al.* 2000), LSM for average daily gain of all genotypes have performed small fluctuations (Figure 5). After this point, all daily average gain values are significantly lower than that of point 72 for the range 75->78 (P<0.01). In other words, for genotype H, 75->78 range can be named the stress zone in average daily gain. This case is similar for BS genotype and the stress zone lasts up to about 78 (P<0.01). After this point, daily average gain starts to increase. Although average daily gains have decreased after 72 THI-1 values for S and ABC genotypes, these weren't statistically significant. In other words, there weren't stress zones for S and ABC between 72->78 THI-1 values (Figure 5).

LSM and SE of average daily gains for THI-1 by genotype were shown in Table 4. According to this, when the THI-1 value reaches 75 from 72 (end of comfort zone), decrease of average daily gain at H and BS genotypes are 89 are 84 g respectively (P<0.01). On the other hand, decrease of average daily gain of S and ABC genotypes start when THI-1 are calculated to be around 84 and 108 g (P<0.01) while it can be said that daily weight losses of all genotypes are nearly the same.

Figure 6 shows the LSM for test day average daily gain, when using average temperature and average humidity (THI-2) in the Equation 3. For all genotypes, daily average gains have increased as THI-2 increases from <54 to 57 (Table 4) and these increases have been found significant (P<0.01). Unlike the THI-1 method, for THI-2 value 57 appears to be the starting point of comfort zone for all genotypes. Along with this, as can be seen in Table 4, the increase of daily average gains for H, BS, S and ABC genotypes as the THI-2 raises from <54 to 57 are around 76, 102, 94 and 182 g respectively (P<0.01). Again, unlike the THI-1 method, the end of comfort zone in THI-2 method is determined to be 66 for H and BS genotypes. For the H genotype, all daily average gains for the 69-78 range have been found to be significantly lower than the ADG at the value 66 (P<0.01). The similar applies for the BS genotype and at value 78 average daily gains begin to rise. In other words, it can be said that when used the THI-2 method, heat stress zones were 69-78 and 69-75 for H and BS genotypes respectively. However, for the S and ABC genotypes, only when the THI-2 value reaches 69, the ADG decreases (P<0.01). These results indicate that a stress zone for H and BS genotypes form only when average temperature and average humidity variables (THI-2) are used. But, unlike H and BS, there was no stress zone for S and ABC genotypes obviously. Because, decreasing average daily gain is statistically significant when THI-2 value reaches only to 69 values (Table 4). Just like in THI-1 method, in analysis made with THI-2 method, it has been concluded that the S and ABC genotypes are a little more endurable to heat stress.

In figure 7 have been presented the LSM regarding ADGs at days of weighing for the THI-3 (maximum heat and humidity). For all genotypes, the ADGs have increased with value of THI-3 increased from <63 to 66 (Table 4). When THI-3 values reached from <63 to 66, increasing ADG has been determined to be 70, 90, 104 and 126 g for H, BS, S and ABC genotypes respectively (P<0.05). In other words, unlike both of THI-1 and THI-2 methods, comfort starting point has been determined to be 66 in THI-3 method. ABC genotype has highest ADG at the start of comfort zone (THI-3=66), when used THI-3 method. And similar to THI-2 method, stress zone wasn't detected for all genotypes (Figure 7). In addition to, when THI-3 value reached to 84, ADGs were lowest for all genotypes. According to these results, 84 THI-3 values can be entitled as stress point for THI-3 method.

Discussion

The coefficients of determination of the values obtained in this study were slightly higher than ones reported by Ravagnolo *et al.* (2000) when THI methods were taken into consideration. This difference could have been caused by the evaluation of different yield types by two researches. In other words, unlike heat stress on average daily gain, Ravagnolo *et al.* (2000) have evaluated heat stress on daily milk yield.

When the THI-1 method is evaluated, after the critical value 72 (Figure 5), genotypes' different reactions to heat-humidity index can be explained with varying tolerance of genotypes to heat tolerance. Although reactions were quite similar for all genotypes (sudden decreasing of ADGs observed at THI=75 and then a slight increase) decreasing ADGs for S and ABC genotypes weren't statistically significant as it was mentioned earlier. With these results, it can be said that H and BS genotypes are more sensitive the maximum heat factor when the air humidity is minimum (THI-1). As can be seen in Figure 2, in the area of research, minimum humidity levels increase along with the maximum heat levels. During the period when the research data was collected, (years 2008-2009) the average maximum air temperature in the region was 24.66 °C, while daily average minimum humidity was only 11.82 % (Table 2). These air conditions created stress zones and resulted with more ADG decreases for H and BS genotypes. However, S and ABC genotypes were affected less by maximum temperature and minimum humidity conditions when compared H and BS genotypes.

With all THI results considered, it is possible to conclude that S and ABC genotypes are more endurable to stress induced by heat increase than H and BS genotypes. However, with THI-2 and THI-3 methods taken into consideration, the index value's increase from the beginning (for THI-2 from <54 to 57 and for THI-3 from <63 to 66) the achievement of the biggest ADG by the ABC genotype yields the conclusion that this genotype is more vulnerable to cold stress.

On the other hand, when the THI methods are compared among each other, it is seen that the starting and ending points of comfort zones are different (Figures 5, 6 and 7). Besides, it can be seen that ADG for any genotype can vary slightly from a THI method to another although they're the same all along. All these results, as stated before, can be explained by the fact that heat and humidity reach their maximum and minimum levels at different times of the day and that animals' reaction to this is diverse (ex. As a geographical feature of the region, when the temperature reaches its highest, the humidity is at its lowest). Besides, as Figures 2, 3 and 4 relating the term meteorological data was recorded is evaluated, the extreme fluctuations of humidity curve compared to the moderate movements of the heat curve supports this conclusion.

In the research, especially with the THI-3 method where maximum heat and maximum humidity parameters are employed, when heat reaches its maximum within the day, humidity drops to its lows and that creates the illusion that stress zones do not occur. However, one of the most important atmospheric incidences that create stress in animals is the existence of high humidity along with high or low temperature. Therefore, it can be said that THI-3 method is not as practical as other methods with the calculation of yield losses upon the stress induced by the rise in the temperature.

Mader *et al.* (2006) reported that a THI between 70 and 74 is an indication to producers that they need to be aware of the potential of heat stress in livestock and THI values ≤74 are classified as alert, 74<THI<79 as danger, and 79≤THI≤84 as emergency for Angus feedlot cattle. These findings were similar to our results especially when THI-1 and THI-3 were used. However, when THI-2 was used, alert point of index was found lower in this study for H, BS and S. This can be caused by using average temperature and humidity values in THI-2 method as mentioned earlier. In addition, obtained findings on feedlot cattle which are reported by Mader *et al.* (2006) and findings from our study for dairy cattle showed that there wasn't a large difference of THI values as the starting points of heat stress between dairy and feedlot cattle. On the other hand relatively low temperature and high humidity could have raised the energy need by yielding to changes in metabolic activation (Figure 1), and this in return might have adversely affected the daily weight gains for H, BS and S genotypes. These findings support the reports of Brouček *et al.* (2006).

In this study, loss of yield was observed in low levels relatively. This situation could have been caused by the simplifications in this study. Firstly, the temperature and humidity were measured away from the farm (9.04 km). Secondly, mean values of maximum temperature, minimum temperature, maximum humidity, minimum humidity, average temperature and average humidity of the 33-day period were calculated in order to detect the weather effect between test days. Thirdly, large effect on test-day performance that was not included in our study was caused by the use of heat-abatement system such as canopy and sprinklers. As there is no adequate and numerical data regarding sprinklers such as duration and timing, so this effect couldn't be used in the model. Therefore, it is possible that hotter days with heat-abatement measures used are less stressful for cattle than cooler days without applications of such measures.

Meteorological data obtained from weather forecast stations offer precious information concerning the effect of heat and humidity on the feedlot. Considering genotype, H and BS are more sensitive to heat stress when compared to S and ABC. However, ABC genotype was more sensitive to cold stress when compared to other genotypes. High and low temperatures were tolerated by cattle to a degree; however, increase in the amount of moisture in the air resulted with low tolerance.

Results from this study indicated that trends of temperature and humidity in the air were important factors for THI calculation types when data from the weather stations were used. Because it gives useful information about which combination of temperature and humidity values (maximum, minimum or average) best reflect the heat stress for genotype. This study was carried out with only one herd and could be repeated with more herds with hourly THI's that are calculated with hourly recorded temperature and humidity values and with two groups such as shaded and non-shaded herds.

Acknowledgements

The authors thank Assist. Prof. Ali İkinci from Drupe and Pome Fruits R&D and Gardening unit of Harran University Agriculture Faculty for providing weather data. Also, authors wish to acknowledge the anonymous referee for helpful comments and suggestions.

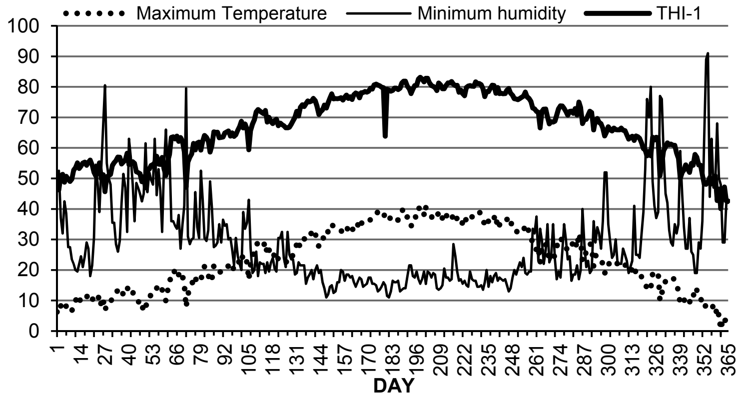

Figure 2
THI-1 values based on daily maximum temperature and daily minimum humidity in Sanliurfa province. All variables (maximum temperature and minimum humidity) in the calculation of THI-1 are the averages of 2008-2009 years.

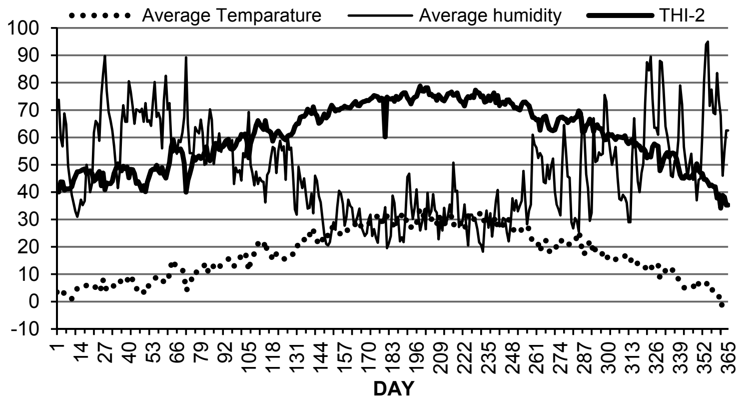

Figure 3
THI-2 values based on daily average temperature and daily average humidity in Sanliurfa province. All variables (average temperature and average humidity) in the calculation of THI-2 are the averages of 2008-2009 years.

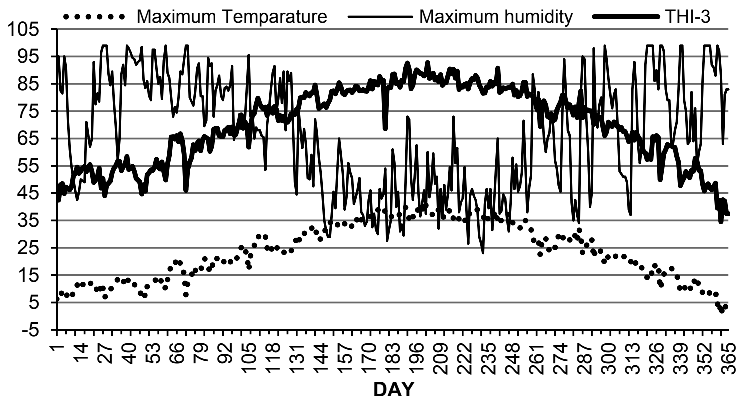

Figure 4
THI-3 values based on daily maximum temperature and daily maximum humidity in Sanliurfa province. All variables (maximum temperature and maximum humidity) in the calculation of THI-3 are the averages of 2008-2009 years.

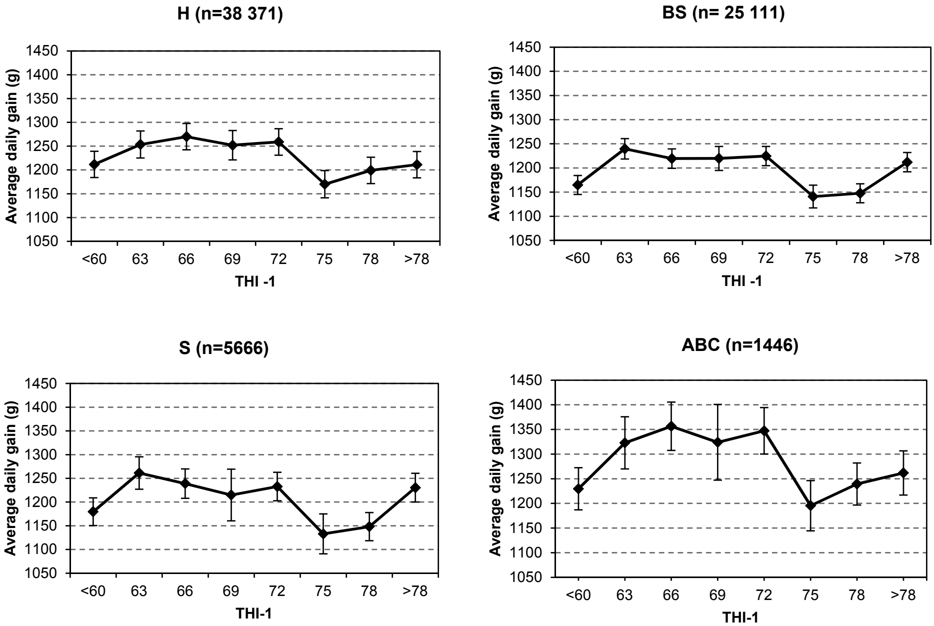

Figure 5
Relationship between the THI-1 for maximum temperature and minimum humidity and the average daily body gain by genotype H: Holstein, B: Brown Swiss, S: Simmental and ABC: Anatolian Black Crossbreed.

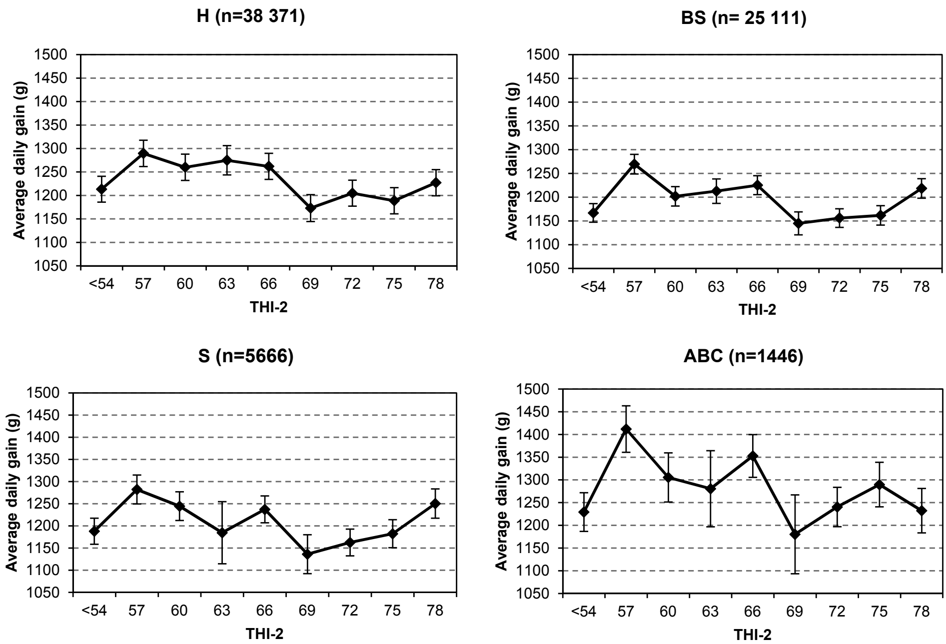

Figure 6
Relationship between the THI-2 for average temperature and average humidity and the average daily body gain by genotype H: Holstein, B: Brown Swiss, S: Simmental and ABC: Anatolian Black Crossbreed.

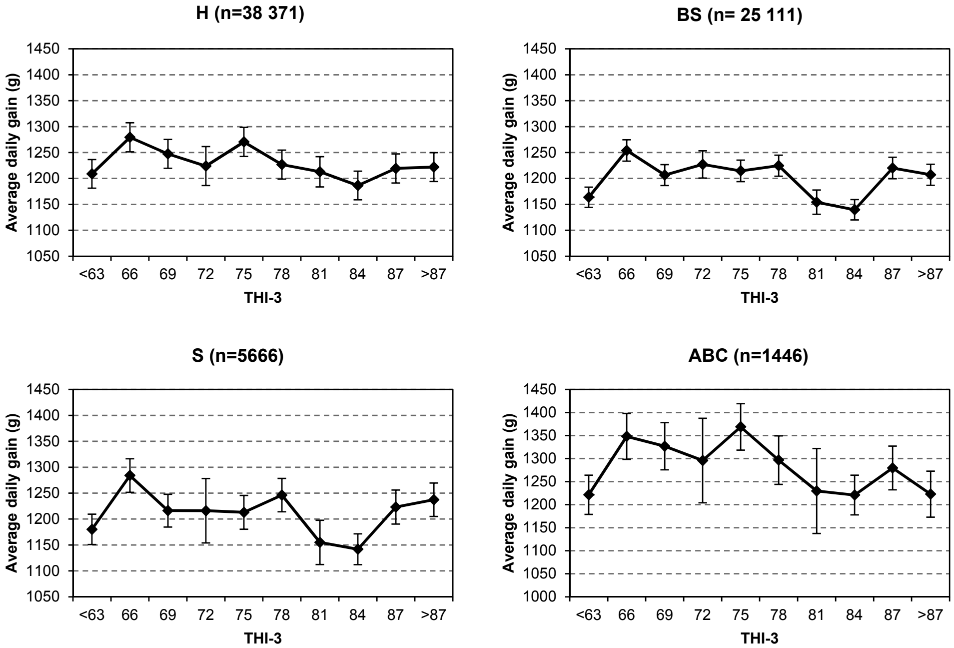

Figure 7
Relationship between the THI-3 for maximum temperature and maximum humidity and the average daily body gain by genotype H: Holstein, B: Brown Swiss, S: Simmental and ABC: Anatolian Black Crossbreed.

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