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Effects of Heat Stress on Dairy Cattle

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Abstract

In the design of dairy cattle shelters, behavior of the animals, climatic environmental factors and herd management have a significant impact. The most important function of dairy cattle barns to protect animals from unfavorable environmental conditions and to increase productivity will be achieved per animal providing with adequate housing environment for them. The most three important factors affecting yield in livestock raising are genetic, nutrition and environmental conditions, respectively. These three factors in order to achieve the highest level efficiency from the animals should be handled at the same time. Stress factors in dairy cattle are composed of structural, climatical and social environments. The stress resulting from the climatic environmental conditions occur due to changes of climatic values in the environment in which hosted of the animals. The most important parameter affecting the productivity of dairy cattle is climatical factors. Climatic environmental conditions consist of temperature, air velocity, relative humidity, solar radiation and light etc. parameters. The temperatures within the climatic environmental conditions are more important with regards to can exhibit normal behavior of the animals and their ability to sustain physiological activities. In dairy cattle, associated with rise above of optimum temperature zone of temperature will be broken heat balance of the body and the animals will enter the heat stress if this excess heat does not take away the of body. Shortly after the start of heat stress, declines will occur in milk yield and animal losses will be inevitable if necessary precautions are not taken. In this review, studies conducted related to in dairy cattle breeding how it should be of climatic environmental conditions suitable to animal behavior and effects on dairy cattle of heat stress were summarized.

Keywords: Behavior, critical temperatures, dairy cattle, heat stress, temperature, Temperature-Humidity Index (THI)

INTRODUCTION

It is increasing the need for animal food products along with a growing world population .The need for animal foodstuffs will be possible by increasing the yield to be obtained from available animal existence while providing the environmental conditions required for animal welfare. In dairy cattle, the most important parameter indicating the productivity is annual milk production per animal.

Accordingly, the average milk production was 2.942 tons animals^{-1} in Turkey while 9.9 tons animals^{-1} in USA and 6.6 tons animals^{-1} in European Countries (Anonymous, 2012). Although dairy cattle presence of Turkey was 20% of the European Countries average, milk production was 7% of that. Inappropriate environmental conditions, deficiency in nutrition and genetic structure can be showed among the major results of this (Uzal &Ugurlu, 2008).

Ugurlu & Uzal (2004) reported that first of all, to reach a high efficiency level of a living, namely the increase of productivity, was closely related stress factor in its the environment where in alive and stress consisting of tension resulting from various factors on live organism was slowing down the generative functions of the live and caused significant yield reduction. In dairy cattle barns, climatic environmental conditions should be checked to ensure animal welfare are temperature, relative humidity, air velocity, solar radiation and light. An animal must be in thermal equilibrium with its environment which radiation, air temperature, air velocity and humidity to maintain homeothermy (Kadzere et al. 2002). Animal surrounding environment influences the heat exchange between the environment and animals. Especially, environmental temperature is the most important factor in the regulation of the heat produced by the animal and in the maintenance of body temperature. To increase of animal production, kept at the desired level and the protection of the health of animals, in animal barns must be between certain limits in of temperature (Mutaf & Sönmez, 1984).

The animals entering heat stress will try to remove extreme heat in their bodies through the latent heat dissipation. Dairy cattle are trying to remove excess heat in the form of water vapor increasing respiration rate to latent heat dissipation. In the meantime, to live deal with excess heat issues is provided the reduction of heat generation stimulating the heat-sensing center in the brain. To reduce of heat production, the live significantly reduces feed intake and occurs lack of appetite. Yield decreases with a reduction in feed intake.

In the increase of animal production three main factors: genetic structure, care-feeding and environmental conditions. To increase of productivity in animal production, cattle breeds with high efficiency genetically should be developed and it must be made of the breeding of this race. Environmental conditions, because it is the factors that regulate living comfort at the climatical, structural and social issues in housing environment of the animals, constitute an integral tripartite structure with genetic structure and nutrition in increasing livestock production (Uzal & Ugurlu, 2009).

Proper Temperature Intervals in Dairy Cattle

The income derived from livestock in order to increase within economical constraints, relations with animal husbandry of climate factors need to understand and evaluate. While investigating effects on the animals of climatic factors, before each should be considered separately, then it must also be focused on their jointly effects. Besides the influences on yield of climatic factors, there are also indirectly effects on disease, care and nutrition.

These effects constitute different results in various animal species and in different races within the same species (Atasever et al. 2004). Heat stress, as directly or indirectly, affects on feed intake, body temperature, maintenance needs, milk yield, reproduction performance, behavior and illness rate of the animals (Thatchet, 1974; Cook et al. 2007; Tucker et al. 2007; Rhoads et al. 2009). In one study, Shinde and Teneja (1986) reported that Between milk yield and climatical factors was a usually negative and significant correlation and they stating that temperature and humidity affected animals and there should be between 25 °C and 7 °C of comfort zone (optimal temperature interval) for maximum milk yield.

The body temperature of dairy cows varies between 38-39.3 °C, with an average of 38.6 °C. The optimum temperature for most farm animals ranges from 10-20 °C. Even in high humidity conditions, cattle produce well in temperatures between 4-24 °C.

So long as it's not very sudden temperature fluctuations, very low temperatures, such as -10 °C, have very little effect. When the temperature exceeds 25 °C, there is a drop in milk production. This decrease can be up to 50% at temperatures of 32 °C and higher. However, the appropriate temperature for cattle adapted to mild climates ranges from 15 to 27 °C and milk production begins to fall when temperatures rise above 35 °C (FAO, 2016). Heat stress occurs when average temperatures are higher than the temperature. Lactating dairy cattle prefer to average temperatures between 5-25 ^{0}C in optimum temperature zone (Roenfeldt, 1998). At ambient temperature above 26 ^{0}C, cattle are forced to cool their bodies and enter heat stress (Kadzere et al. 2002).

Reactions of the cattle to temperatures above optimal temperature zone are different (Kadzere et al. 2002). These contain respiration increased rates and rectal temperature (Omar, 1996), raised panting and drooling and reduced heart rates (Blazquez, 1994) besides decreased milk production (Keown & Grant, 1997) and feed intake (Rhoads et al. 2004). Appropriate temperature for cattle examined by many researchers is the suitable temperatures between 0-24 °C temperature values and is the optimum temperatures between 7-15 °C temperature values (Demir, 1992). Comfort zone temperature contains a limited range and temperature values remaining within this region is considered as optimum temperatures (Ekmekyapar & Okuroğlu, 1984).

Optimum temperature limits for dairy cattle is 10–20 °C (Webster, 1994). Although suitable temperature values for cattle is 4-24 °C, the optimum temperature values 10-15 °C and the optimum temperature lower limit 7 °C, in temperatures above 24 °C begins to decrease milk production in dairy cattle. Indeed, associated with rise to 35 ^{0}C of temperature reduce by 50% milk production (Ekmekyapar, 1991). Optimum, suitable, lower and upper critical temperatures in cattle are given in Table 1.

Water loss by evaporation from the skin increases in temperatures above 20 (Berman, 1968). Upper critical temperature for dairy cattle, regardless of their milk production or previous climate adaptation is 25-26 degrees (Berman et al. 1985). When the heat which cannot be removed from the body exceeds heat loss capacity by evaporation, body temperature increases and animals die from hyperthermia if unchecked (Kadzere et al. 2002).

Table 1. Optimum, suitable, lower and upper critical temperature values to cattle

Lower Critical Temperatures (^{0}C)		**Optimum Temperatures (^{0}C)**		**Suitable Temperatures (^{0}C)**	**Upper Critical Temperatures (^{0}C)**	
-10 (FAO, 2016)	-15 (WMO, 1989)	7-25 (Shinde & Teneja, 1986)	10 (Maton et al. 1985)	0-24 (Demir, 1992)	25-26 (Berman et al. 1985; NRC, 1989)	>25 (Sainsbury & Sainsbury, 1988; FAO, 2016)
-12 (to Holstein, Brown Swiss) -1(to Jersey) (Yeck & Stewart, 1959; Young, 1981)	- 14 (pregnant and dry) -25 (in the peak period of lactation) (Radostits & Blood, 1985)	10-20 (Sainsbury & Sainsbury, 1988; Webster, 1994 FAO, 2016)	10-15 (Sainsbury, 1974; Balaban & Şen, 1988; Ekmekyapar, 1991; Okuroğlu & Yağanoğlu, 1993; Anonymous, 2015)	5-25 (Roenfeldt, 1998; Anonymous, 2015)	>21 (to higly productive and elderly animals) (Johnson,1987; Doležal, 2004)	21-27 (Blackshaw & Blackshaw, 1994; Doležal et al. 2004)
-10 (draught free) 2 (2 ms^{-1} wind speed) (Noton, 1982)	-26 (0.2 ms^{-1} wind speed) -13 (2 ms^{-1} wind speed) (Webster, 1981)	7-15 (Demir, 1992; Yüksel, 1993)	0-20 (Brody, 1955)	4-24 (Ekmekyapar, 1991; FAO, 2016,9	>26 (Kadzere et al. 2002) 27 (WMO, 1989)	25 (Radostits, and Blood, 1985) 25-27 (NRC, 1981)
-6 (Sainsbury & Sainsbury, 1988)	<(-5) or <(-10) (Williams, 1959)	5-15 (WMO, 1989)		0-20 (Wathes et al. 1983)	>24 (Ekmekyapar, 1991; West, 2003)	21-25 (to Jersey) 30-32 (to Brown Swiss) (Brody, 1955)
<(-7) (Sainsbury, 1974)					> 27 (Brouček, 1997)	28 (Wathes et al. 1983)

Developed indexes to determine the level of heat stress is called as THI (Temperature-Humidity Index). THI is determined with various formulas developed of researches by measuring dry bulb, wet bulb, dew point temperatures and relative humidity of air and the dairy cattle is confirmed whether the heat stress or not. According to various researchers, THI is determined using the following formulas.

$THI = (0.15 * T_{db} + 0.85\ T_{wb}) * 1.8 + 32$, (Bianca, 1962) (1)

$THI = (0.35 * T_{db} + 0.65\ T_{wb}) * 1.8 + 32$, (Bianca, 1962) (2)

$THI = (1.8 * T_{db} + 32) - [(0.55 - 0.0055 * RH) * (1.8 * T_{db} - 26.8)]$, (NRC, 1971) (3)

$THI = T_{db} + 0.36 * T_{dp} + 41.2$, (Yousef, 1985) (4)

$THI = 0.72 * (W + D) + 40.6$, (Kadzere et al. 2002) (5)

$THI = t_{ba} + 0.36 * t_{pr} + 41.2$, (ASABE, 2006) (6)

$THI = (0.8 * T_{db}) + [(RH / 100) * (T_{db} - 14.4)] + 46.4$, (Mader et al. 2006) (7)

$THI = (1.8 * T + 32) - ((0.55 - 0.0055 * RH * (1.8 * T - 26))$, (Titto et al. 2011) (8)

In these formulas, Tdb, t_{ba} and D are dry bulb temperature (^{0}C); Twb and W are wet bulb temperature (^{0}C); T_{dp} and t_{pr} are dew point temperature (^{0}C); RH is relative humidity (%).

Gantner et al. (2011) point out that the THI is 72, which corresponds to a temperature of 22 ^{0}C at 100% relative humidity, 25 ^{0}C at 50% relative humidity or 28 ^{0}C at 20% relative humidity and milk production at higher THI values than 72 is affected by heat stress. Milk yield of dairy cattle decrease by 0.3 kg per animal compared to each unit increase of THI value (Gantner et al. 2011). Similarly, milk yields of cows decreased by 1.8 kg along with per unit increment of average ambient temperature (Johnson, 1963; Smith et al. 2012).

Zimbelman et al. (2009) reported that decrease in the level of milk production started out 65 and over of the THI value. THI is used to measure thermal comfort in most studies and for dairy cows generally considered to be the upper limit THI $\geq$72. Milk yield of cows on this level generally reduce due to the heat stress (Igono et al. 1992; Ravagnolo & Misztal, 2002; Gaughan et al. 2008; Armstrong, 1994). THI values low from 71comfort zone, 72-79 mild stress, 80-90 average stress and values greater than 90 were defined as extreme stress zone. Furthermore, Kadzere et al. (2002) reported that THI values of 70 or less were comfortable, 75-78 stressful, and lactating dairy cattle were not to maintain the body heat balance in values greater than 78 and this situation caused extreme stress. The effects of THI on stress and behavior in dairy cattle are shown in Figure 1 and Table 2.

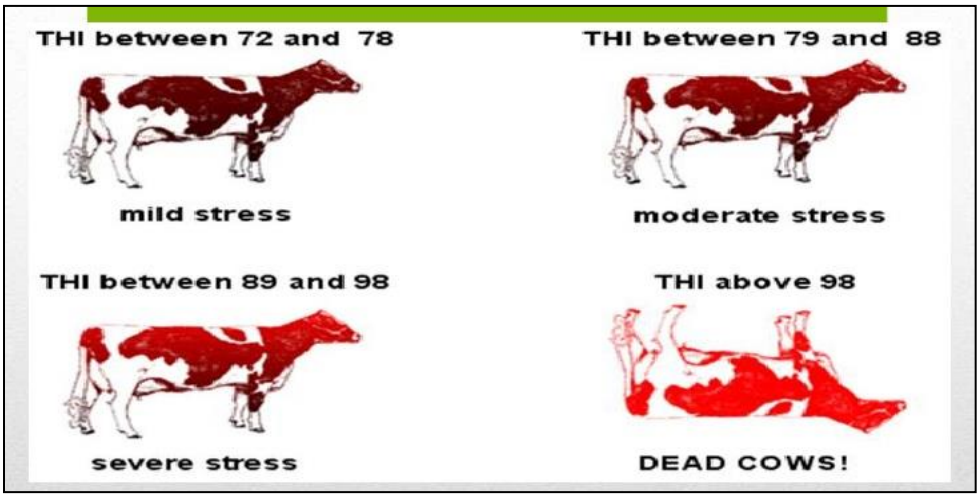


Figure 1. The effects of the temperature-humidity index in dairy cattle (Anonymous, 2016a)

Table 2. Effect of heat stress on dairy cattle (Anonymous, 2016b)

THI	Stress Level	Comments
<72	None	-
72-79	Mild	❖ Dairy cows will adjust by seeking shade, increasing respiration rate and dilation of the blood vessels. ❖ The effect on milk production will be minimal.
80-89	Moderate	❖ Both saliva production and respiration rate will increase. ❖ Feed intake may be depressed and water consumption will increase. ❖ There will be an increase in body temperature. ❖ Milk production and reproduction will be decreased.
90-98	Severe	❖ Cows will become very uncomfortable due to high body temperature, rapid respiration (panting) and excessive saliva production. ❖ Milk production and reproduction will be markedly decreased.
>98	Danger	❖ Potential cow deaths can occur.

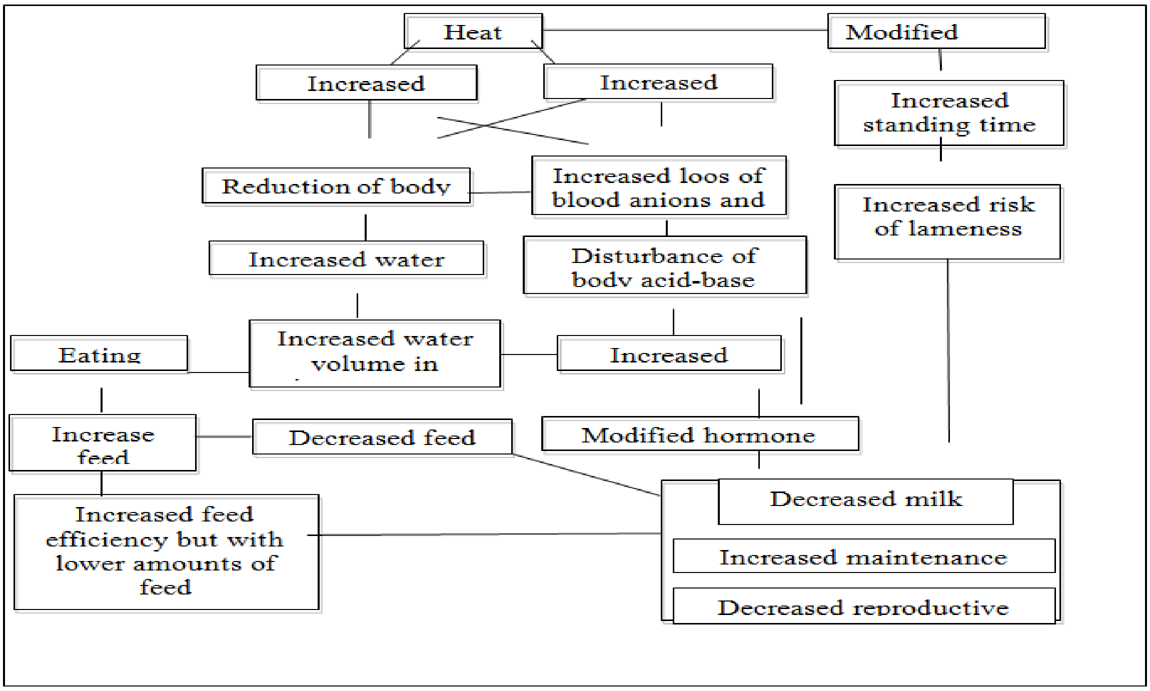
Effect on Behavior of Heat Stress

Normal behavior of dairy cows exposed to heat stress varies. In particular, standing behavior is a behavior that in hot environmental conditions should be monitored for dairy cattle (Cook et al. 2007; Legrand et al. 2011). In lactating cows begins to decline feed intake at average 25-26 ^{0}C temperatures and this fall is drops more quickly in temperatures above 30 ^{0}C (NRC, 1989). Bandaranayaka and Holmes (1976) stated that fat and protein content of milk decreased at 30 ^{0}C when feed intake was kept at the both temperatures by working with two pairs Jersey cow exposed to either 15 ^{0}C or 30 ^{0}C air temperature.

In a study, Schneider et al. (1988) reported that dairy cattle in heat stress consumed less feed (13.6 vs. 18.4 kg day^{-1}), more water (86.0 vs. 81.9 lt day^{-1}) and produced less milk (16.5 vs. 20.0 kg day^{-1}) than cows in a suitable temperature zone. Dry matter intake and eating activity frequency all day long reduce in heat stress conditions. This activities increase at the evening, night and early morning hour (Schneider et al. 1988). Rhoads et al. (2004) stated that their reduced feed intake when cows exposed to heat stress and simultaneously care needs increased due to the activation of the temperature regulating system, milk production declined 2 days after heat stress and feed intake decreased within 1 day after start of heat stress. According to Collier et al. (1981), maximum decrease in milk yield during heat stress occurs within 48 hours after the onset of stress.

When ambient temperature rises above 25-26 °C, decrease in feed consumption and mild yield occurs and when temperature exceeds 32 °C, milk yield reduce at 3-20% rates (Keown & Grant, 1997). Cows with the increase of the heat load spend more time in the shade and they spend less time to lying (Ansell, 1981; Schütz et al. 2010). Rates of cattle rested in upright position or performed rumination is linearly increasing as temperature increases (Shultz, 1984). By cows standing, maximize evaporation from the body surface and benefit from convection derive from wind (Frazzi et al. 2000). With an increasing average temperature or solar radiation, cattle are more likely to seek shades or other cooling structures (Atrian & Shahryar, 2012). General effects of heat stress in dairy cattle are given in Table 3.

Table 3. Schematic depiction of the general effects of heat stress in dairy cattle, (Atrian & Shahryar, 2012)



CONCLUSIONS

When a general assessment is made, it is important that the shelters do not create climatic stress on the livings. In order to achieve this condition, free systems that allow the cattle to use different areas within the structure at different times are more advantageous. In order to protect cattle from the adverse effects of high temperatures, especially areas where will occur sufficient shadow and airflow should be provided.

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REFERENCES

Anonymous, 2012. http://www.ulusalsutkonseyi.org.tr (accessed 04 May 2015)

Anonymous, 2015b. http://www.zootekni.org.tr (accessed 30 April 2015)

Anonymous, 2015c. Hayvan Barınakları. http://www.fidantarımsaldanismanlik.com (accessed 30 April 2015)

Anonymous, 2016a. Dairy Cattle Heat Stress. http://www.slideshare.net/thermalaid1/dairy-cattle-powerpoint (accessed 23 August 2016)

Anonymous, 2016b. Climate Change Impact on Dairy Cattle. http://www.uvm.edu (22 June 2016)

Ansell R. H. 1981. Extreme Heat Stress in Dairy Cattle and its Alleviation: A Case Report. In: Clark JA (ed.), Environmental Aspects of Housing for Animal Production, Buttherworths, London, pp. 285-306.

Armstrong D. V. 1994. Heat Stress İnteraction With Shade And Cooling. *J. Dairy Sci*. 77, 2044–2050.

ASABE 2006 Standards 53rd Edition, Design of Ventilation Systems for Poultry and Livestock Shelters, in ASAE EP270.5 FEB03, American Society of Agricultural and Biological Engineers, St. Joseph, Michigan (USA), 652-670.

Atasever Ş., Erdem H. & Kul E. 2004. Süt Sığırlarında Verim Üzerine Etkili Bazı İklimsel Stres Faktörleri, *4. Ulusal Zootekni Bilim Kongresi* 209-216.

Atrian P. & Shahryar H. A. 2012. Heat Stress In Dairy Cows (a review). *Res. in Zoology*, 2, 31-37.

Bandaranayaka D. D. & Holmes C. W. 1976. Changes in the Composition of Milk and Rumen Contents in Cows Exposed to a High Ambient Temperature with Controlled Feeding. *Trop. Anim. Health Prod.* 8, 38-46.

Balaban A. & Şen E. 1988. Tarımsal Yapılar, *Ankara Ünv. Ziraat Fak. Yayınları*, No: 721, Ankara.

Berman A. 1968. Nychthermeral and Seasonal Patterns of Thermoregulation in Cattle. *Aust. J. Agric. Res.* 19, 181-188.

Berman A., Folman Y. M., Kaim M., Mamen Z., Herz D., Wolfenson A. & Graber Y. 1985. Upper Critical Temperatures and Forced Ventilation Effects for High-Yielding Dairy Cows in a Tropical Climate. *J. Dairy Sci.* 68, 488-495.

Bianca W. 1962. Relative Importance of Dry-and Wet-Bulb Temperatures in Causing Heat Stress in Cattle. *Nature,* 195, 251–252.

Blackshaw J. K. & Blackshaw A. W. 1994. Heat Stress in Cattle and the Effect of Shade on Production and Behaviour. *Aust. J. Exper. Agric.* 34, 285–295.

Blazquez N. B., Long S. E., Mayhew T. M., Perry G. C., Prescott N. J. & Wathes, C. M. 1994. Rate of Discharge and Morphology of Sweat Glands in the Perineal, Lumbodorsal and Scrotal Skin of Cattle. *Res. Vet. Sci.* 57, 277-284.

Brouček J. 1997. Effect of High Temperatures on Cattle. *Agriculture, 43*, 522–542.

Brody S. 1955. Climatic Physiology of Cattle. *Missouri Agric. Exp. Stn. J., Series* 1607.

Collier R. J., Eley R. M., Sharma A. K., Pereira R. M. & Buffington D. E. 1981. Shade Management in Subtropical Environment for Milk Yield and Composition in Holstein and Jersey Cows. *J. Dairy Sci*. 64, 844-849.

Cook N. B., Mentink R. L., Bennett T. B. & Burgi K. 2007. The Effect of Heat Stress and Lameness on Time Budgets of Lactating Dairy Cows. *J. Dairy Sci*. 90, 1674-1682.

Demir Y. 1992. Kapalı Ahırlarda İç Ortam Sıcaklık ve Nemin Dış Ortam Sıcaklık Neminden Etkileniminin Belirlenmesi Üzerine Bir Araştırma. *IV.Ulusal Tarımsal Yapılar Ve Sulama Kongresi*. Erzurum**:** 376-384.

Doležal O., Knížková I., Kudrna V., Dolejš J., Kunc P., Gregoriadesová J. & Černá D. 2004. Thermal Stress in Dairy Cattle – Tactics and Strategy (in Czech). VÚŽV Uhříněves, Praha, pp.56

Ekmekyapar T. & Okuroğlu M. 1984. Yumurta Tavuğu Kümeslerinde Uygun Çevre Koşulları. *Teknik Tavukculuk Dergisi,* 45, 3-14.

Ekmekyapar T. 1991. Hayvan Barınaklarında Çevre Koşullarının Düzenlenmesi. *Atatürk Üniversitesi Ziraat Fakültesi Yayınları* No:306, Erzurum.

FAO. 2016. Animal Environmental Requirements. http://www.fao.org (accessed 26 December 2016)

Frazzi E., Calamari F., Calegari F. & Stefanini L. 2000. Behavior of Dairy Cows in Response to Different Barn Cooling Systems. *Transactions of the ASAE, American Society of Agricultural Engineers* 0001-2351/ 00 / 4302-387, 43(2), 387-394.

Gantner V., Mijić P., Kuterovac K., Solić D. & Gantner R. 2011. Temperature-Humidity Index Values and Their Significance on the Daily Production of Dairy Cattle. *Mljekarstvo*, 61(1), 56-63.

Gaughan J. B., Mader T. L., Holt S. M. & Lisle, A. 2008. A New Heat Load Index for Feedlot Cattle. *J. Anim. Sci*., 86, 226-234.

Igono M. O., Bjotvedt G. & Sanfordcrane H. T. 1992. Environmental Profile and Critical temperature effects on milk-production of Holstein cows in desert climate. *Int. J. Biometeorology*. 36(2), 77-87.

Johnson H. D., Ragsdale A. C., Berry I.L. & Shanklin M. D. 1963. Temperature-Humidity Effects Including Influence of Acclimation in Feed and Water Consumption of Holstein Cattle. *Misso-uri Agr. Exp. Sta. Res. Bul*. 846.

Johnson H. D. 1987. Bioclimate Effects on Growth, Reproduction and Milk Production. In: Johnson Harold D. (ed.), Bioclimatology and the Adaptation of Livestock. World Animal Science, B5, Chapter 3, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, pp. 35–57.

Kadzere C.T., Murphy M.R., Silanikove N. & Maltz E. 2002. Heat Stress in Lactating Dairy Cows: A Review. *Livestock Production Science* 77, 59-91.

Keown F. J. & Grant R. G. 1997. How to Reduce Heat Stres in Dairy Cattle. http://www. unl.edu/IANR/PUBS/extnpubs/dairy/1063 html.

Legrand A., Schütz K. E. & Tucker C. B. 2011. Using Water to Cool Cattle: Behavioral and Physi-ological changes associated with voluntary use of cow showers. *J. Dairy Sci.*, 94(7), 3376–3386.

Mader T. L., Davis M. S. & Brown-Brandl T. 2006. Environmental Factors Influencing Heat Stress in Feedlot Cattle. *J. Anim. Sci*., 84, 712–719.

Maton A., Daelemans J. & Lambrecht J. 1985. Housing of Animals, *Elsevier Science Publishers B.V.*, Netherlands.

Mutaf S. & Sönmez R. 1984. Hayvan Barınaklarında İklimsel Çevre ve Denetimi, *Ege Üniv. Ziraat Fak. Yayınları* No: 438, E., Ü., Zir. Fak. Ofset Basımevi, Bornova-İzmir.

NRC (National Research Council). 1989. In: Revised Edition Update. Nutrient Requirements of Dairy Cattle. *National Academy Press*, Washington, DC.

Noton, H.N., 1982. Farm Building. By the College of Estate Management White Knights, Reading *RGGZAW*, London.

NRC (National Research Council). 1971. A Guide to Environmental Research on Animals. *Natl. Acad. Sci.*, Washington, DC.

NRC (National Research Council). 1981. Effect of environment on nutrient requirements of domestic animals. BARR Comm. On Animal Nutrition, Board on Agriculture, National Research Council. *National Academy Press*, Washington, DC.

NRC (National Research Council). 1989. In: Revised Edition Update. Nutrient Requirements of Dairy Cattle. *National Academy Press*, Washington, DC.

Okuroğlu M. & Yağanoğlu A. V. 1993. Kültürteknik, *Atatürk Üniversitesi Ziraat Fakültesi Ders Yayınları,* No: 157, Erzurum.

Omar E. A., Kirrella A. K., Soheir A., Fawzy A. & El-Keraby F. 1996. Effect of Water Spray Followed by Forced Ventilation on Some Physiological Status and Milk Production of Post Calving Friesian Cows. Alex. *J. Agric. Res.* 4, 71-81.

Radostits O. M. & Blood D.C. 1985. Herd Health W.B. Saunders, Phikadelphia pp. 176-182.

Ravagnolo O. & Misztal I. 2002. Effect of Heat Stress on Nonreturn rate in Holsteins: Fixed-Model Analyses. *J. Dairy Sci.* 85(11), 3101-3106.

Rhoads M. L., Rhoads R. P. VanBaale J. J., Collier R. J., Sanders S.R., Weber W. J., Spiers B. A., Spain D. E. J. N., Sampson J. D. & Rhoads R. P. 2004. Use of Physiological Parameters to Predict Milk Yield and Feed Intake in Heat-Stressed Dairy Cows" *J. Therm. Biol*. 29, 759-764.

Rhoads M. L., Rhoads R. P., VanBaale, M. J., Collier R. J., Sanders S. R., Weber W. J., Crooker B. A. & Baumgard L. H. 2009. Effects of Heat Stress and Plane of Nutrition on Lactating Holstein Cows: I. Production, Metabolism, and Aspects of Circulating Somatropin. *J. Dairy Sci.* 92, 1986-1997.

Roenfeldt S. 1998. You can't Afford to Ignore Heat Stres. *Dairy Manage.* 35(5), 6-12.

Sainsbury D. W. B. 1974. Health Problems in Intensive Animal Production. In "Environmental Aspects of Housing for Animal Production", J.A. Clark (ed.), Butterworths, London.

Sainsbury D. & Sainsbury P. 1988. General Environmental Effects. In "Livestock Health and Housing", D. Sainsbury and P. Sainsbury (ed.), ELBS, Bailliere Tindall, London.

Schneider P. L., Beede D. K. & Wilcox C. J. 1988. Nycterohemeral Patterns of Acid-Base Status, Mineral Concentrations and Digestive Function of Lactating Cows in Natural or Chamber Heat Stres Environments. *J. Anim. Sci*. 66(1), 112-125.

Schütz K. E., Rogers A. R., Poulouin Y. A., Cox N. R. & Tucker C. B. 2010. The amount of Shade Influences the Behavior and Physiology of Dairy Cattle. *Journal of Dairy Science* 93, 125-133.

Shinde S. & Taneja V. K. 1986. Effect of Physical Environment Dairy Milk Yield in Crossbreds, *Amin. Breed. Abst.* 54(12), 7668.

Shultz T. A. 1984. Weather and Shade Effects on Cow Corral Activities. *J. Dairy Sci.* 67(4), 868-873.

Smith J. F. Collier R. J. Harner J. P. & Bradford B. J. 2012. Strategies to Reduce Heat Stress in Dairy Cattle. *27th Annual Southwest Nutrition and Management Conference Book*, 65-84.

Thatchet W. W. 1974. Effects of Season, Climate and Temperature on Reproduction and Lactation. *J. Dairy Sci*. 57, 360-368.
Titto C. G., Titto E. A. L., Titto R. M. & Mourao G. B. 2011. Heat Tolerance and the Effects of Shade on the Behavior of Simmental Bulls on Pasture. *Animal Science Journal*, 82, 591-600.
Tucker C. B., Rogers A. R. & Shutz K. E. 2007. Effect of Solar Radiation on Dairy Cattle Behaviour, Use of Shade and Body Temperature in a Pasture-Based System. *Appl. Anim. Behav. Sci.* 109, 141-154.
Uğurlu N. & Uzal, S. 2004. Süt Sığırı Barınaklarının Tasarımında Mevsimsel Etkiler. *Selçuk Üniversitesi Ziraat Fakültesi Dergisi*, 18(33), 73-79.
Uzal S. & Uğurlu N. 2008. The Effect of Climatic Condition on Area Preference of Animals in Dairy Cattle Houses. *J. Int. Environmental Application & Science*, 4, 224-233.
Uzal S. & Uğurlu N. 2009. The Effects of Seasons on the Area Usage of Animals in Freestall Dairy Cattle Barn. *International Coference Lake and Nutrient Loads Alblakes* 09, April 24-25, pp. 240-245.
Wathes C. H. Webster A. J. F.& Charles D. R. 1983. Ventilation, Air Hygiene and Animal Healty, Farm Housing, The Veterinary Record 113, 554-559.
Webster A. J. F. 1981. Optimal Housing Criteria for Ruminants. In "Environmental Aspects of Housing for Animal Production", J.A. Clark (ed.), Butterworths, London.
Webster A. J. F. 1994. Comfort and Injury. In "Livestock Housing", C.M. Wathes and D.R. Charles (ed.), *University Press*, Cambridge, pp. 49-67.
West J. W. 2003. Effects of Heat-Stress on Production in Dairy Cattle. *J. Dairy Sci*., 86, 2131-2144.
Williams C. M. 1959. Influence of Winter Conditions on the Feed and Water Intake of f Feedlot Steers. *J. Anim. Sci*. 18, 1155.
WMO. 1989. Animal Health and Production at Extremes of Weather (Reports of the CAgM Working Groups on Weather and Animal Disease and Weather and Animal Health). Technical Note No. 191 (WMO-NO. 685), Genova.
Yeck R. G. & Stewart R. E. 1959. A Ten-Year Summary of the Psychoenergetic Laboratory Dairy Cattle Research at the University of Missouri. *Trans.* ASAE 2, 71–77.
Young B. 1981. Cold Stress as it Affects Animal Production. *Journal of Animal Science*, 52 (1), 154-163.
Yousef M. K. 1985. Stress Physiology: Definition and Terminology (Basic Principles), In: Stress Physiology in Livestock Vol. 1. CRC Press, Boca Raton, FL, Eds, p.
Yüksel A. N. 1993. Kültürteknik, *Trakya Üniversitesi Tekirdağ Ziraat Fak. Yayın* No: 182. Ders Kitabı No: 19, Tekirdağ.
Zimbelman R. B., Rhoads R. P., Rhoads M. L., Duff G. C., Baumgard L. H. & Collier R. J. 2009. A Re-evaluatio of the Impact of Temperature Hu-midity index (THI) and Black Globe Temperature Humidity Index (BGHI) on Milk Production in High Producing Dairy Cows. *Proc. 24th Southwest Nutrition and Management Conference*, *Tempe,* AZ, 158-168.