

EXTREME METEOROLOGICAL CONDITIONS AND METABOLIC PROFILE IN HIGH YIELDING HOLSTEIN-FRIESIAN DAIRY COWS

CONDIȚIILE METEOROLOGICE EXTREME ȘI PROFILUL METABOLIC AL VACILOR DE RASĂ HOLSTEIN-FRIZĂ CU PRODUCȚII MARI DE LAPTE

GERGÁCZ, Z.*, †BÁDER, E.*, BRYDL, E.***, KOVÁCS, A.*, SZÜCS, E.*

*Faculty for Agricultural and Food Science, University of West Hungary,
Mosonmagyaróvár,
Faculty for Veterinary Science, Szent István University, Budapest, Hungary*

The impact of two years (2002 and 2003) with different summer temperature extremes on variation in metabolic profile was analyzed in blood and urine samples taken from healthy, primiparous (n = 371) and multiparous (n = 795) high yielding Holstein-Friesian dairy cows. In this study main focus was lead on three most critical physiological phases, thus cows were assigned into three groups as follows: (1) dry cows for 10 days prior to calving; (2) cows 1-30 days after delivery, and (3) cows with more than 31 days post partum. Findings reveal clear response of the cows to heat in selected blood (hemoglobin, plasma aceto-acetic-acid, FFA, AST, glucose, urea) and urine (pH, NABE and urea) parameters. In the majority of cows, glucose and hemoglobin level, one of the most significant blood parameters, indicated symptoms of insufficient energy supply. Further metabolic indicators differed more or less from reference values depending on actual condition. Due to heat load dry matter intake has been decreased even by 10-15 per cent in primiparous cows. They were expected to increase body weight and size and simultaneously produce attain at large milk yields. In doing so that cows would have require large amount of nutrients. Out of parameters such as hemoglobin, glucose, FFA, AST and blood-urea differed from the reference values in most cases; however, this phenomenon seemed to be present in almost every case for hemoglobin and glucose. The lack of energy caused by heat stress can be contributed to the decrease of dry matter intake which has been indicated by the urea levels and pH both in blood and urine prevailing unfavorable and insufficient feeding practice. The results reconfirm the need to reconsider both the actual feeding practice (e.g. to increase of nutrient content in rations, reduce the intake of soluble proteins in rumen, pay attention of crude fiber in Total Mixed Rations (TMR), NDF and ADF, avoid overfeeding of inorganic buffers, to control moisture content in TMR, increase of Na and K intake), and construction of cowsheds with ample airspace, good ventilation and cooling system by remodeling of existing dairy operations.

Key words: dairy cows, heat stress, energy balance, corrective actions in feeding practice and remodeling

Introduction

In dairy cows performance, well being and health status are influenced by various biometeorological factors. Out of them the most significant are the high environmental temperature in summer and the extreme cold in winter as well as cooling effect of wind. Consequently, protection against short term, acute stress seems to require reasonable strategies, technologies and technical solutions when running dairy operations to maintain permanent well being of animals at a high level (Szücs et al, 2001). Chronic heat stress and long term high environmental temperature along with high relative humidity seems to be serious risk factors in dairy production (Ádám, 1962; Barótfi and Rafai, 1985). Heat may reduce both milk yield and reproductive performance, as well as feed intake in the dairy cow, and affect metabolic heat production (Flamenbaum et al., 1986, 1995; Johnson, 1985; Yousef, 1985). Thus, performance of high yielding dairy cows can be influenced by extreme weather conditions due to detrimental effects on metabolism of the animals. For this reason, analysis of metabolic profile of cows exposed to heat stress seemed to be justified.

Extreme high temperature conditions in summer can not be excluded in Hungary in the future according to long-term climate forecasts. The cows indicate the forthcoming hot days by their behavior. The symptoms are drastic, such as lack of appetite followed by decrease of milk yield. Under commercial conditions in semi-covered cowsheds using deep litter the highest daily milk yields can be attained within the range of 11 and 20°C. Below -1°C decrease in daily milk yield may be 4-5 per cent. The depression in yield above 21°C may exceed 3 per cent (Szücs et al, 2001 a, b, c and d; Kovács and Szücs, 2006). After some days, the body condition decreases (cows loose weight) due to declining dry matter intake. In addition, to the visible and measurable detrimental impacts serious economic damages may occur by poor health status and subsequent reproduction failures. The situation can be more aggravated by incorrect feeding practice as response. The effects can be detected by analysis in samples taken from blood and urine and defined by metabolic profile test. The results exactly indicate the prevalent risk factors by feeding disorders and inappropriate housing conditions. Thus, the aim of this study was to analyze impacts of extreme weather conditions by metabolic profile of blood and urine in high yielding dairy cows. Findings reveal considerable variances in primiparous cows as compared to multiparous ones. The most important phenomenon is decrease of dry matter consumption. In the first parity the dry matter intake should be more by at least 10-15 per cent to meet the requirements for high milk yield. In the first parity, heifers can attain and maintain high milk yields for prolonged time in case of high dry matter intake. In addition, first-calf heifers have to gain body size, because they attain the mature live weight only in the third lactation. Accordingly, factors decreasing their dry matter intake such as summer heat might be critical.

The advised climate factors in cow sheds are 8-15°C in the case of temperature, 65-85% in the case of relative humidity, and 0.15-0.25 m/s in the case

of air-flow speed. The animals' food intake decreases already at 22°C and the milk production can decrease even by 50% above 30°C. The rectal temperature of the cows exceeds 39.0°C after some hours in 26-30°C, and the milk production decreases notably in the case of cows with high performance. These animals take in much feed for the high performance, and they can hardly get rid of the heat caused by burning the feed. The blood's creatinine content rises with the increasing body temperature, as the respiration and the pulse (Kovács 1990). Flamenbaum et al. (1995) during examinations of dairy cows found out that the temperature of animals placed in cooled stables were 38.9 °C, while animals exposed to heat stress suffered 39.7°C. The milk production of the first group was higher by 1.9 kg and the daily water consumption was less by 9 liters than in the case of the other group.

The cattle react sensitively to high environmental temperature. By cooling of cow-shed e. g. water-spraying combined with forced ventilation, the harmful effect of heat stress decreases by 10 % due to higher dry matter intake of cows (Chen, K.H., et al., 1993). Berman and Meltzer (1973) already focused the attention to the fact that the increasing dry matter intake caused by heat stress intensifies the fat mobilization, so it means a risk factor for the energy balance and health status in the very first part of lactation.

As a rule, dairy cow has negative nutrient balance in the first weeks of lactation. After delivery, the cow needs high amount of energy from body reserves, actually she is not capable to cover the required nutrients consumed, the consequence of which is loss of body weight. The energy and protein requirement increases by four and ten times from calving until the peak of lactation, respectively, as Várhegyi (1999) stated. In this period the cow has to mobilize the energy and fat reserves to cover the energy needed for milk production. A number of authors consider 42-55 kg per condition unit as average bodyweight change in Holstein-Friesian dairy cows (Ducker et al., 1985; Grainger et al., 1982). Morrow (1976) reported that the consequence of rapid loss in condition after calving may account risk factors for the cow's health status with simultaneous loss of feed intake, decrease of milk production and reproduction indices, especially in fat individuals. According to Gillaund et al., (2001) that the healthy cows' body condition steeply decreases for 42 days, then it remains unchanged (does not decrease below 3 points). The condition of the cows in the cetogenic group decreases for 90 days. Garnsworthy and Topps (1982) reported that cows starting the lactation with higher condition score loose relatively more points during lactation increasing the risk of ketosis. Thus the aim of this study was to analyze the extreme meteorological conditions on dairy cows' energy status by analyses of metabolic profile.

Materials and Methods

Blood and urine samples were taken from clinically healthy primiparous and multiparous cows selected at random in two consecutive years (2002 and 2003) in the summer period. In the first year, collection of samples covered 29 and 32 large scale dairy operations, respectively. Samples were assigned to physiological groups according to reproduction status and phases of lactation (Group 1: 1-15 days prior

to calving, Group 2: 1-30 days after calving and Group 3: more than 31 days post partum). Samples were taken after the morning feeding between 3-5 hrs AM.

In 2002 mean monthly temperatures ranged between 18.8 and 21.8°C for the period covered from May until the end of August (with regular weather conditions). The year 2003 was dryer and hotter than the average and the monthly mean temperatures ranged between 20.0 and 24.1°C (with hot weather conditions). Temperature was registered by Szeged, Siófok and Győr Stations of National Meteorological Services (NMS) next to the dairy operations for the summer months lasting from May until the end of August. Distributions of days with extremely hot and normal temperatures ($T_{\max} \geq 30^{\circ}\text{C}$ and $T_{\text{average}} \geq 20^{\circ}\text{C}$) for NMS Stations are presented in Table 1.

Table 1

Distribution of hot days and days with average daily temperatures

Stations of National Meteorological Service	Number of days	
	$T_{\max} \geq 30^{\circ}\text{C}$	$T_{\text{average}} \geq 20^{\circ}\text{C}$
Győr		
2002	36	78
2003	56	94
Difference, %	155	121
Siófok		
2002	30	96
2003	44	112
Difference, %	147	117
Szeged		
2002	48	93
2003	68	110
Difference, %	142	118

For analyses of metabolic status the Metabolic Profile Test (MPT) developed by Brydl et al. (1987) was used, which has been widely applied recently in dairy operations in Hungary. MPT provides information about the energy status of cows, or indirectly refers to some disadvantageous metabolic processes that distract energy from production. Reference values characterizing the metabolism of dairy cows are as follows in blood: hemoglobin 5.0-7.9 mmol/l. Plasma: aceto-acetic-acid <0.1-0.2 mmol/l; FFA <0.2 mmol/l; AST < 80 U/l, glucose 3.0-3.9 (>2.3) mmol/l; blood urea 3.3-5.5mmol/l. and urine: pH 7.8-8.4; NABE >+100 mmol/l normal, NABE =0-100 mmol/l acid load, NABE<0 mmol/l danger of metabolic acidosis; urine urea 130-300 mmol/l. Thus,

energy turnover is analyzed by aceto-acetic-acid in blood, glucose of plasma and free fatty acids within the system. Several researchers drew attention to the relation of ketosis and condition. Fat mobilization illness or other derangement of liver can be deduced by the higher AST (aspartate-transaminase). Conclusions can be drawn from the urea concentration of plasma for the quantity and quality of the proteins and carbohydrates easily soluble in the rumen. The absolute quantities and proportions reflect the normal rumen fermentation. The urea quits the blood through the kidneys and saliva. The value measured in the blood is determined by the equilibrium of the synthesis in the liver, filtration through the kidney and reabsorption.

Results and Discussions

Findings of this study for primiparous and multiparous cows are presented in Table 2 and 3, respectively. In comparison to milder weather conditions in 2002 with that of extremely hot summer in 2003 reveal clear differences in metabolic profile prior to delivery, in the first month post partum and from the second months on for hemoglobin, glucose and FFA as indicator of energy turnover. Clear differences were established in comparison to reference values by Brydl et al. (1987) for metabolic indicators in a previous study.

a) Metabolic profile of primiparous cows

Metabolic profile for primiparous cows is presented in Table 2. Findings show comprehensive decrease of hemoglobin in all groups at high level of probability in the year 2003 with hot weather conditions ($P \leq 0.001$). Energy deficiency due to hot weather conditions is reconfirmed by the decrease of glucose, too. Differences between mean values for groups for cows 10 days prior to delivery, and those up to 30 vs. from 31 days of lactation were $P \leq 0.001$ and $P \leq 0.05$, respectively. The most critical situation occurred in the very first phase, up to 30 days post partum, where the glucose level attains at lower margin of reference value in the hot year indicating the risk of hypoglycemia.

Aceto-acetic-acid increases only at moderate rate for all groups in the hot year 2003 ($P \leq 0.10$). The levels in the hot summer, however, reach the marginal value of 0.1 mmol/l one of the first sign of risk for subclinical ketosis. After 31 days post partum the value is within the range of reference values.

The best indicator of duration of the period with energy deficiency is FFA. Due to reduced dry matter intake the phenomenon is getting even worse. Results of this study seem to reconfirm the tendency. In the hot summer, FFA values were also increasing prior to calving significantly ($P \leq 0.05$), without attaining the limit of 0.2 mmol/l. In the most critical period, within 30 days after delivery, increase of FFA was also significant exceeding the reference limit (0.23 mmol/l, $P \leq 0.01$), which intensifies fat mobilization indicating risk of ketosis. From the 31st day on the FFA level goes down below the limit.

AST reveals liver function. In primiparous cows AST levels were within normal range prior to calving in both years (figures did not exceed reference values). In spite of this, due to enhanced inroad of liver AST values decreased both in 2002 and 2003 (99 U/l) and exceeded the limits of reference value (80 U/l) 31 days post partum. The differences were significant ($P \leq 0.05$ level of probability). In relation to enhanced fat mobilization (FFA values) and proliferation of ketonic bodies (acet-acetic-acid) in the blood the values refer to unambiguous symptoms of disintegration of liver cells.

Blood urea provides information on the cows' protein provision. Urea indicates quantity and quality of feed protein, first of all in terms of in rumen degradable protein (RDP) and in rumen undegradable protein (RUP). Blood urea level might be influenced by liver function disorders, as well. In Hungarian dairy farms overfeeding of high RDP is a common phenomenon causing reproduction failures, and additionally, it might evoke heavy energy deficiency in the first phase of lactation. In this study, blood urea shows significant effect in primiparous cows ($P \leq 0.01$). In hot summer its value exceeded the reference value (5.4 mmol/l). Especially for heat stress overfeeding of RDP should be avoided (Higginbotham et al., 1989; Nianogo et al., 1991). Findings of this study reconfirm conclusions of previous experiments; the means for blood urea levels exceed maximum limits, even though differences between two years statistically were not significant.

Based on experiences gained on acidosis due to selective feed intake, relative fiber deficiency and enhanced feeding of concentrates in hot summer periods for years, analysis of urine pH and Net-Acid-Base-Excretion (NABE), feeding of chemical buffers such as sodium bicarbonate and magnesium oxide, became a common practice. NABE values reveal success in aim at the goal. Risk of acidosis was reduced, but urine pH values underpin the conclusion that overfeeding could evoke temporary alkalosis. In urine samples of primiparous cows no statistical differences were present for pH between the investigated years, however, in 2003 with hot summer average attained the highest limit of reference with 8.4 mmol/l. Overuse of buffers is indicated by the mean pH = 8.6 for the cow group within 30 days post partum in comparison with that of pH = 8.3 for 2002 ($P \leq 0.01$). No significant differences were calculated in cows from 31 days on (pH = 8.5 and pH = 8.6), however, both figures seem to exceed reference limits.

Net-Acid-Base-Excretion (NABE) reveals acid production already prior to calving. The risk includes opportunity for further physiological natural acidosis at delivery causing further decrease of dry matter intake. Between mean values of the analyzed years significant differences were calculated ($P \leq 0.01$), however, acid load was recorded only in 2002. The 2003 year „normal” value (111 mmol/l) coincides with pH = 8.6 indicating overfeeding of buffers.

In line with blood urea significant differences between years were present only in cows prior to calving accompanied with marked increase in the hot summer (154 and 325 mmol/l, ($P \leq 0.001$) exceeding the maximum of reference (300 mmol/l). No significant differences were registered in any of groups and years exceeding reference limits.

In conclusion, heat stress may strengthen negative status of energy deficiency in primiparous cows, increase the risk of ketosis which, in addition, might contribute to further aggravation by feeding disorders by improper protein and buffer supply in commercial practice.

b) Metabolic profile of multiparous cows

Under hot weather conditions AST values show moderate increase in cows up to 30 days post partum at $P \leq 0.1$ level of probability exceeding the range limits of reference in both years 2002 and 2003. Extreme high AST value (103 U/l) was present immediately after delivery indicating exaggerated inroad of liver.

Prior to calving blood urea shows marked increase exaggerated within the range of normal reference values (4.0 and 4.8 mmol/l). In spite of the fact values refer to inappropriate protein supply. In cow group within 30 days post partum the averages for 2002 and 2003 were 6.7 and 6.1 mmol/l ($P \leq 0.001$), respectively. Explanation of this phenomenon is that hot temperature decreases the appetite (and dry matter intake), consequently the relative protein over consumption as feeding failure decreases.

Urine pH exceeds reference values in both years and cow groups post partum. The message is possible overuse of buffers as feed additive. However, differences do not seem to be significant.

Values for Net-Acid-Base-Excretion indicate acid inroad only prior to calving without any statistical probability in either groups.

Urine urea level significantly ($P \leq 0.01$) increases only in group prior to delivery in consequence of heat load as it has already been shown in a similar way in blood urea without attaining the upper limit of reference value. In post partum cows' values for 2002 are higher, especially in cows 31 days after calving with high level of probability ($P \leq 0.001$) without attaining the upper limit. Figures follow just the same tendency as it has occurred for blood urea.

While in multiparous cows detrimental effects of hot environmental conditions are clearly shown by hemoglobin and glucose, in primiparous counterparts informative value of other parameters does not seem to be incomplete enough.

Theory and base of adaptation of requirements of domestic animals to climatic conditions have been discussed by Barótfi and Rafai (1985) in detail. It was emphasized that simultaneous chronic i.e. long term heat stress and high relative humidity may be a serious risk factor in dairy production. Szücs et al (2001 a, b, c and d) stated that on herd level highest daily milk yields can be recorded between 11 and 20°C, consequently this range might be considered as optimum temperature under Hungarian conditions.

Table 2

Indicators of Metabolic Profile Test for primiparous cows in two consecutive summer periods

Item	2002			2003			P
	N	Mean	SD	N	Mean	SD	
Group 1: dry cows 1-10 days prior to calving							
Hemoglobin (mml/l)	28	6.7	1.5	19	5.4	0.7	***
Glucose (mmol/l)	27	4.0	1.1	19	3.4	0.9	*
Aceto-acetic-acid (mmol/l)	28	0.06	0.02	19	0.07	0.02	+
FFA (mmol/l)	28	0.11	0.06	19	0.15	0.07	*
AST (U/l)	28	69	19	19	67	32	NS
Blood urea (mmol/l)	28	3.9	2.0	19	5.4	1.2	**
Urine pH	28	8.0	1.0	19	8.4	0.6	NS
NABE(mmol/l)	28	65	66	19	58	53	NS
Urine urea (mmol/l)	28	154	86	19	325	155	***
Group 2: cows 1-30 days after calving							
Hemoglobin (mml/l)	93	6.4	1.3	91	5.3	0.5	***
Glucose (mmol/l)	93	3.2	0.9	91	2.3	0.9	***
Aceto-acetic-acid (mmol/l)	93	0.07	0.05	91	0.1	0.09	*
FFA (mmol/l)	93	0.18	0.11	91	0.23	0.17	**
AST (U/l)	93	93	29	91	99	35	NS
Blood urea (mmol/l)	93	5.2	1.6	91	5.5	1.6	NS
Urine pH	93	8.3	1.0	91	8.6	0.5	**
NABE (mmol/l)	93	85	61	91	111	64	**
Urine urea (mmol/l)	93	245	98	91	243	120	NS
Group 3: more than 31 days post partum							
Hemoglobin (mml/l)	89	5.9	0.7	51	5.2	0.6	***
Glucose (mmol/l)	77	3.0	0.8	45	2.4	0.8	***
Aceto-acetic-acid (mmol/l)	89	0.06	0.04	51	0.07	0.03	NS
FFA (mmol/l)	89	0.09	0.05	51	0.08	0.05	+
AST (U/l)	89	91	25	51	103	37	*
Blood urea (mmol/l)	89	6.3	1.3	51	6.2	2.2	NS
Urine pH	89	8.5	0.5	51	8.6	0.3	NS
NABE (mmol/l)	89	129	66	51	132	81	NS
Urine urea (mmol/l)	89	263	100	51	277	107	NS

NABE=Net-Acid-Base-Excretion

*** = P<0.001, ** = P<0.01, * = P<0.05, P<0.10

Table 3

Indicators of Metabolic Profile Test for multiparous cows in two consecutive summer periods

Item	2002			2003			P
	N	Mean	SD	N	Mean	SD	
Group 1: dry cows 1-10 days prior to calving							
Hemoglobin (mml/l)	101	6.4	0.8	72	5.5	0.6	***
Glucose (mmol/l)	99	3.7	0.9	65	2.9	2.90.8	***
Aceto-acetic-acid (mmol/l)	101	0.05	0.01	72	0.06	0.03	*
FFA (mmol/l)	101	0.13	0.18	72	6.16	0.15	+
AST (U/l)	101	66	18	72	63	20	NS
Blood urea (mmol/l)	101	4.0	1.6	72	4.8	1.6	**
Urine pH	101	8.1	0.9	72	8.3	0.8	NS
NABE (mmol/l)	101	77	77	72	81	70	NS
Urine urea (mmol/l)	101	174	93	72	215	105	**
Group 2: cows 1-30 days after calving							
Hemoglobin (mml/l)	181	6.1	0.9	144	5.3	0.7	***
Glucose (mmol/l)	170	2.8	0.8	132	2.2	0.7	***
Aceto-acetic-acid (mmol/l)	181	0.10	0.14	145	0.08	0.09	NS
FFA (mmol/l)	181	0.23	0.19	145	0.21	0.15	NS
AST (U/l)	181	95	32	145	103	70	+
Blood urea (mmol/l)	181	5.9	1.5	145	5.4	1.6	**
Urine pH	181	8.4	0.8	145	8.5	0.6	NS
NABE (mmol/l)	181	109	72	145	107	72	NS
Urine urea (mmol/l)	181	247	97	145	232	116	NS
Group 3: more than 31 days post partum							
Hemoglobin (mml/l)	201	5.9	0.7	95	5.0	0.6	***
Glucose (mmol/l)	182	2.9	0.8	91	2.3	0.8	***
Aceto-acetic-acid (mmol/l)	201	0.06	0.03	95	0.07	0.04	NS
FFA (mmol/l)	201	0.08	0.04	95	0.09	0.06	*
AST (U/l)	201	91	28	95	91	34	NS
Blood urea (mmol/l)	201	6.7	1.5	95	6.1	1.7	***
Urine pH	201	8.6	0.7	95	8.7	0.3	NS
NABE (mmol/l)	201	133	69	95	143	74	NS
Urine urea (mmol/l)	201	272	106	95	223	115	***

NABE= Net-Acid-Base-Excretion

*** = P<0.001, ** = P<0.01, * = P<0.05, + = P<0.10

In comparison to the mean in above temperature range 1.5-1.7 kg (4-4.7%) decrease was recorded in the range of -10 and -1°C, i.e. 0 -10°C ones. The depression of daily milk yield above 21°C proved to be 1.1 kg (3.1%). Positive effect of increased temperature differences between daily maximum and minimum values might be due to improved intensity of internal metabolism. With increasing temperature differences between daily maximum and minimum values, exceeding mainly 21°C, daily milk yield seemed to improve in high producers. Above 86 % relative humidity, daily average milk yield decreased by 1 kg (3%). At low and high daily average temperature levels, which extremely differ from optimum range, the reaction of high and low producer cows, the milk yield of which exceeded 51.0 kg and/or was less than 20.9 kg per day, seemed to be the most sensitive ones. Most severe depression in daily milk yield was established due to high relative humidity, first of all in high producers.

The effect of weather conditions on milk production is possibly manifested in their interactions. Obvious interaction of daily average temperature and relative humidity in depression of milk yield and its actual and/or relative deviation was established. No or small effect of increase of relative humidity was present on depression in milk yield between 11 and 20°C daily average temperature. Similarly, small depression was established in milk yields due to relative humidity in case of large daily maximum and minimum temperature differences. The effects of environmental temperature and humidity on milk yield and/or health status is realized through metabolic processes of dairy cows. Combined physiological effect of environmental temperature and relative humidity has been established in an early study by Habeeb et al. (1989) and Johnson (1985), as well.

Conclusions

In conclusion

- reduced feed intake increases energy deficiency and makes metabolism worse which has been indicated by enhanced glucose and FFA values
- just the same or even worse situation is present in primiparous cows even though for them, higher energy supply would be needed in the first phase of lactation over the requirement for maintenance and ascending daily milk production for body development as well
- energy deficit is enhanced by reduced appetite due to heat stress
- heat stress reduces absorption in digestive system and cause relative nutrient deficiency
- to reduce adverse effects of heat stress evaporative cooling should be applied
- upgrading housing condition would be justified with high shelter and channel ventilation.

For this reasons corrective actions are needed in commercial feeding practice on large scale dairy operations to avoid potential risk of metabolic disorders in high yielding cows in the peripartum period due to energy deficiency.

Bibliography

1. **Ádám, T.** (1962)- *Újabb adatok a nyitott és zárt tehénistállók összehasonlító klimatikus vizsgálatáról.* Állattenyésztés, 11, 33
2. **Barótfi, I., P., Rafai** (1985)- *Energiagazdálkodás az állattartásban.* Mezőgazdasági Kiadó, Budapest
3. **Berman, A., A., Meltzer, A** (1973)- *Critical temperature in lactating dairy cattle: a new approach to an old problem.* Int. J. Biometeorol., 17, 167
4. **Brydl, E., S., Gönye, G., Sályi** (1987)- *A nagyüzemi szarvasmarha-állományok átfogó, komplex takarmányozási és állategészségügyi értékelési rendszere,* MÉM Értesítő, 15, 5845.
5. **Chen, K.H., T. J., Huber, C. B. Theurer, D. B., Armstrong, R. C., Wanderley, J. M., Nderley, M., Simas, S. C., Chen, J. L., Sullivan** (1993)- *Effect of protein quality and evaporative cooling on lactational performance of Holstein cows in hot weather.* J. Dairy Sci., 76, 819
6. **Ducker, M.J., R.A. Haggett, W.J., Fisher, S.V., Morant, G.A., Bloomfield** (1985)- *Nutrition and reproductive performance in dairy cattle. 1. The effect of level of feeding in late pregnancy and around the time of insemination on the reproductive performance of first lactation dairy heifers.* Anim. Prod., 41, 1
7. **Ferguson, J. D., D. T. Galligan and N. Thomsen.** (1994)- *Principal descriptors of body condition score in holstein cows.* J. Dairy Sci., 77, 2695
8. **Flamenbaum, I., D., Wolfenson, M., Mamen, A., Berman** (1986)- *Cooling dairy cattle by a combination of sprinkling and forced ventilation and its implementation in the shelter system.* J. Dairy Sci., 69, 3140 (a)
9. **Flamenbaum, I., D., Wolfenson P. L., Kunz, M., Maman, A., Berman** (1995)- *Interactions Between Body Condition at Calving and Cooling of Dairy Cows During Lactation in Summer.* J. Dairy Sci., 78, 2221 (b)
10. **Garnsworthy, P.C., J.G., Topps** (1982)- *The effect of body condition at calving, food intake, and performance on blood composition of dairy cows given complete diets.* Anim. Prod., 35, 121.
11. **Gillind, P., O., Reksen, Y. T., Gröhn, -K., Karlberg** (2001)- *Body condition related to ketosis and reproductive performance in Norwegian dairy cows.* J. Dairy Sci., 84, 1390
12. **Grainger, C., G.D., Wilhelms, A. A., McGowan** (1982)- *Effect of body condition at calving and level of feeding in early lactation on milk production of dairy cows.* Aust J. Exp. Agric. Anim. Husb., 22, 9
13. **Habeeb, A. A., A. M., Abdel-Samee, T. H., Kamal** (1989)- *Effect of heat stress, feed supplementation and cooling technique on milk yield, milk composition and some blood constituents in Friesian cows under Egyptian conditions.* Proceedings of 3rd Egyptian-British Conference on Animal Production, Vol. 2. Alexandria, Egypt, 629
14. **Higginbotham, G.E., M. Torabi, and J.T. Huber.** (1989)- *Influence of dietary protein concentration and degradability on performance of lactating cows during hot environmental temperatures.* J. Dairy Sci. 72:2554

15. **Johnson, H. D.** (1985): *Physiological responses and productivity of cattle.* (In: Yousef, M. K., ed. *Stress physiology in livestock. Basic principles.*) Boca Ration, Florida. CRC Press. Vol. 1. 4
16. **Kovács, A., E. Szücs** (2006)- *Meteorológiai tényezők hatásai a szarvasmarhák életfolyamataira és teljesítményére.* Állattenyésztés és Takarmányozás, 55, 54
17. **Kovács, F.** (1990)- *Állathigiénia,* Mezőgazdasági Kiadó, Budapest. 112.
18. **Morrow, D.A.** (1976)- *Fat cow syndrome.* J. Dairy Sci., 59, 1625
19. **Nianogo, A.J., H.E. Amos, M.A. Froetschel, C.M. Keery** (1991)- *Dietary fat, protein degradability and calving season: effect on nutrient use and performance of early lactating cows.* J.Dairy Sci., 74, 2243
20. **Szücs, E., J.Mika, Z., Nagy, T. A. N. Tuan, I., Györkös, A., Kovács** (2001)- *Effect of meteorological factors on milk production in Holstein-Friesian cows.* 52nd Annual Meeting of the European Association for Animal Production, Budapest-Hungary 26-29 August, 2001 (a)
21. **Szücs, E., J.Mika, Z., Nagy, T. A. N. Tuan, I., Györkös, A., Kovács** (2001)- *Meteorológiai tényezők szerepe a holstein-fríz tehenek tejtermelésben. 1. közlemény: A napi időjárás-változás hatásai.* Állattenyésztés és Takarmányozás, 50. 3. 215-228. p. (b)
22. **Szücs, E., J., Mika, Z. Nagy, A.N., Tuan, O. I., Györkös, A. Kovács** (2001)- *Meteorológiai tényezők szerepe a holstein-fríz tehenek tejtermelésben. 2. közlemény: A napi időjárási elemek hatása a tejtermelés színvonalára.* Állattenyésztés és Takarmányozás, 50, 333 (c)
23. **Szücs, E., J.Mika, Z., Nagy, T. A. N. Tuan, I., Györkös, A., Kovács** (2001)- *Meteorológiai tényezők szerepe a holstein-fríz tehenek tejtermelésben. 3. közlemény: A napi időjárási elemek kétszeres kölcsönhatásai.* Állattenyésztés és Takarmányozás, 50, 521 (d)
24. **Várhegyi, J., I., Várhegyi** (1999)- *A holstein-fríz tehén kondícióbírálat.* Herceghalom
25. **Yousef M. K.** (1985)- *Thermal environment.* (In: Yousef, M. K., ed. *Stress physiology in livestock. Basic principles*) Boca Ration, Florida. CRC Press. 1, 10