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ANALYSIS OF PRODUCTION TRAITS AND MICROCLIMATE PARAMETERS ON DAIRY CATTLE FARMS

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Abstract: Aiming determination of the variability of production traits (daily milk yield and composition) and microclimate parameters (ambient temperature and humidity) in the barns; as well as the correlation between the analyzed groups of traits, 1,636,192 test-day records from Simmentals and 1,275,713 test-day records from Holsteins were analysed. Performed analysis indicate high variability of production traits due to cow's breed, parity as well as breeding region. Also, high variability of microclimate parameters in the barns due to season and breeding region was found. Furthermore, statistically highly significant ($p < 0.001$) correlations between the production traits and microclimate parameters were determined. Finally, the negative effect of inadequate microclimate on daily milk production was determined in both breeds in all breeding regions. Since genetic evaluation and selection of dairy cattle for heat resistance is only long-term method for heat stress managing, determined effect will be taken into account in the statistical model for estimation of genetic parameters and breeding values.

Key words: production traits, dairy cows, microclimate parameters

Introduction

As climate change has become a pervasive topic in global agricultural production, thus, heat stress in Europe is becoming a growing problem in livestock production especially in dairy cattle breeding *(Gauly et al., 2013)*. Every day we are witnessing faster and more pronounced climate change around the world. These changes will result in increasingly unfavourable climatic conditions for agricultural and especially livestock production *(IPCC, 2007).* For instance, *Reiczigel et al. (2009)* in Hungary, as well as *Dunn et al. (2014)* in UK indicated an increase of heat stress days per year. *Almeida et al. (2011)* stated that the optimal ambient temperature for dairy production depends on the species, breed, feed intake, age, acclimatization, yield levels, coat and hair characteristics and also on animal tolerance to heat and cold. Also, accordingly to *Santos Daltro et al. (2017),* high-producing dairy cows are more sensitive to heat stress because, by increasing milk production, cows produce more metabolic heat. In accordance to *Vasconcelos and Demetrio (2011),* selection for milk production reduces the ability of the cow to withstand the stress caused by heat and consequently during the hotter months of the year, increases susceptibility to heat stress and decreases production and reproductive efficiency. Similarly, *Hansen (2013)* stated that the high production makes cows more susceptible to heat stress meaning that heat stress will become, and already is, a problem in intensive dairy breeding systems regardless the climate changes. *Bohmanova (2006)* and *Collier et al. (2006)* determined that production level significantly alter the animal response to heat stress making high production animals more sensitive to heat stress than low production ones. Heat stress adversely affects the milk production and its composition in dairy animals, especially animals of high genetic value *(Bouraoui et al., 2002; West, 2003; Spiers et al., 2004; Upadhyay et al., 2009; Wheelock et al., 2010; Gantner et al. 2011, 2017).* Besides, in heat stressed dairy animals, maintenance requirements of energy also increased by 30% *(NRC, 2007).* Furthermore, heat stress also effects health of dairy animals by imposing direct or indirect affects in normal physiology, metabolism, hormonal and immunity system *(Das et al., 2016). Balfoussia et al. (2014)* determined that the acclimatization to long-term stress results in proteomic changes indicated by expression of proteins related to inflammation, while *Min et al. (2016)* concluded that long-term moderate heat stress may lead to an inflammatory response in dairy cows with significantly increased plasma TNF-α and IL-6, which presents a pro-inflammatory factors. Finally, heat stress induces considerable profit loss *(St-Pierre et al., 2003).* Heat stress is considered to be a combination of temperature and humidity that exceed the comfort zone of a cow. The most common measure of heat stress in dairy cattle is temperature-humidity index (THI) that includes ambient temperature and relative humidity *(Kibler, 1964).* The THI threshold value at which heat stress affects milk production and feed intake vary, depending on study, from 68 to 72 *(Du Preez et al., 1990a, b; Bouraoui et al., 2002; Bernabucci et al., 2010; Gantner et al., 2011; Collier end Hall, 2012),* while *Vitali et al. (2009)* emphasised the increased risk of animals' death at THI = 80. There are numerous methods to reduce the effect of heat stress on dairy cows, that is short-term and long-term methods. Short-term methods include optimization of feeding and application of different cooling systems in farm buildings, while long-term methods mean selection of dairy cattle for resistance to heat stress. Taking into account the unquestionability of climate change, the necessity of adequate adaptation strategies in order to decrease negative effects of climate change on domestic animals was pointed out by *Segnalini et al. (2013).* As preconditions for genetic evaluation and selection of dairy cattle for heat resistance the goals of this study were: 1. Determination of phenotypic variability of the analyzed groups of traits: a. statistical analysis of production traits (daily milk yield and composition) of dairy cows under selection, b. statistical analysis of microclimate parameters (ambient temperature and humidity) in the barns; and 2. Determination of the correlation between the analyzed groups of traits.

Material and Methods

For the analysis of the variability of production traits and microclimate parameters, test-day records of Holstein and dairy Simmental cows reared in Croatia were used. Test-day records were collected during the regular milk recording performed monthly in accordance to the alternative milk recording method (AT4 / BT4) in the period from January 2005 to December 2013. At each recording, measuring and sampling of milk were performed during the evening or morning milkings. Also, at each recording, ambient temperature and relative humidity in the barns were recorded. Based on measured microclimate parameters, temperature-humidity index (THI) was calculated using the following equation by *Kibler (1964)*:

$$THI = 1.8 \times Ta - (1 - RH) \times (Ta - 14.3) + 32$$

Where Ta presents the average temperature in degrees Celsius while RH is the relative humidity as a fraction of the unit. Furthermore, test-day records with lactation stage in (< 5 days and > 500 days), age at first calving in (< 21 and > 36 months), missing parity, missing breed, missing or nonsense daily milk traits (accordingly to ICAR standards, 2017), and missing or nonsense Ta and RH value were deleted from the dataset. After logical control dataset consisted of 1,636,192 test-day records from 117,659 Simmentals (10,599 farms) and 1,275,713 test-day records from 90,159 Holsteins (6,701 farms). Accordingly, to the parity, cows were divided into four classes: I., II., III., and IV. (animals in fourth and higher lactations). Furthermore, accordingly to location of farm, test day records were divided into three breeding regions: Eastern, Central, and Mediterranean. While, in accordance to the recording date, test day records were divided into four recording season: spring, summer, autumn, and winter.

For the logical control of data, determination of the variability of the analyzed groups of traits (production traits and microclimate parameters); and determination of the correlation between the analyzed groups of traits SAS/STAT (*SAS Institute Inc., 2000*) was used.

Results

The variability of production traits of dairy cows that is daily milk yield, daily fat, protein, lactose and urea content as well as somatic cell count accordingly to breed and parity, separately for each region (Eastern, Central, and Mediterranean) is presented in the Tables 1, 2, and 3.

Table 1. Variability (mean; SD) of daily production traits accordingly to breed and parity in Eastern region

Trait / Parity	Holstein				Simmental			
	I.	II.	III.	IV.	I.	II.	III.	IV.
DMY	21.50±7.8	24.23±10.4	24.57±10.7	23.45±10.5	15.42±5.1	16.60±6.1	17.20±6.4	16.61±6.2
DFC	4.09±0.9	4.13±1.0	4.13±1.0	4.11±1.0	4.12±0.9	4.12±0.9	4.10±0.9	4.06±0.9
DPC	3.41±0.4	3.44±0.5	4.00±0.5	3.36±0.45	3.45±0.5	3.49±0.5	3.47±0.5	3.43±0.5
DLC	4.53±0.2	4.44±0.2	4.41±0.2	4.36±0.26	4.57±0.2	4.50±0.2	4.46±0.2	4.42±0.3
DUC	23.24±9.0	23.95±9.2	23.49±9.3	22.67±9.6	21.34±11.6	21.54±11.7	21.70±11.7	21.28±11.6
SCC	16.42±1.9	16.77±2.1	17.07±2.1	17.34±2.2	16.12±2.0	16.44±2.1	16.64±2.1	17.03±2.2

* DMY – daily milk yield (kg); DFC – daily fat content (%); DPC – daily protein content (%); DLC – daily lactose content (%); DUC – daily urea content (mg/ml); SCC – log transformed somatic cell count

In Eastern region, the highest average daily milk yield (DMY) was determined in Holstein breed in third parity, while the lowest DMY was in Simmental breed in first parity. Daily fat content (DFC) was the lowest at the fourth parity in Simmental breed while the daily protein content (DPC) and daily lactose content (DLC) were the lowest in Holstein breed at the fourth parity. Daily urea content (DUC) was the highest at the second parity in Holstein breed. Finally, highest somatic cell count was determined in fourth parity in both breeds, with higher value determined in Holsteins.

Table 2. Variability (mean; SD) of daily production traits accordingly to breed and parity in Central region

Trait / Parity	Holstein				Simmental			
	I.	II.	III.	IV.	I.	II.	III.	IV.
DMY	18.31±6.4	19.55±7.8	19.91±8.0	19.00±7.7	14.86±5.3	15.74±6.2	16.05±6.3	15.17±5.9
DFC	4.26±0.9	4.31±0.9	4.28±0.9	4.20±0.9	4.27±0.8	4.22±0.9	4.22±0.9	4.11±0.9
DPC	3.40±0.5	3.46±0.5	3.41±0.5	3.36±0.5	3.45±0.5	3.51±0.5	3.47±0.5	3.43±0.5
DLC	4.53±0.2	4.45±0.2	4.41±0.2	4.37±0.2	4.57±0.2	4.50±0.2	4.47±0.2	4.43±0.2
DUC	21.13±10.4	20.85±10.4	20.18±10.4	19.43±10.3	19.77±10.2	19.69±10.4	19.45±10.3	18.86±10.2
SCC	16.59±2.1	16.99±2.1	17.23±2.2	17.62±2.2	16.08±2.0	16.41±2.1	16.65±2.1	17.03±2.2

* DMY – daily milk yield (kg); DFC – daily fat content (%); DPC – daily protein content (%); DLC – daily lactose content (%); DUC – daily urea content (mg/ml); SCC – log transformed somatic cell count

In dairy cattle reared in Central region, the lowest value of daily milk yield (DMY) was determined in Simmental breed at first parity, while the highest daily milk production was in Holstein breed at third parity. Daily fat content (DFC) was the highest in Holstein breed at the second parity while daily protein content (DPC) and daily lactose content (DLC) were the lowest at the fourth parity in Holstein breed. Daily urea content (DUC) was the lowest at the fourth parity in Simmental breed, while the highest was at first parity in Holstein breed. Similarly like in cows reared in Eastern region, the highest somatic cell count was determined in cows of both breed in fourth lactation.

Table 3. Variability (mean; SD) of daily production traits accordingly to breed and parity in Mediterranean region

Trait / Parity	Holstein				Simmental			
	I.	II.	III.	IV.	I.	II.	III.	IV.
DMY	21.71±7.7	23.44±9.9	24.20±10.5	22.61±10.7	13.51±5.0	14.19±5.9	14.43±6.1	14.20±5.3
DFC	3.84±0.8	3.88±0.9	3.86±0.9	3.81±0.9	4.17±0.9	4.13±0.9	4.16±1.0	4.12±1.0
DPC	3.35±0.4	3.38±0.4	3.34±0.4	3.26±0.4	3.48±0.4	3.49±0.5	3.43±0.5	3.43±0.4
DLC	4.53±0.2	4.43±0.2	4.40±0.2	4.33±0.3	4.54±0.2	4.48±0.2	4.45±0.2	4.41±0.2
DUC	22.38±8.8	23.24±9.2	23.27±9.4	22.69±9.6	21.04±10.0	22.25±10.6	21.21±10.3	20.66±9.9
SCC	16.05±1.9	16.47±2.1	16.90±2.2	17.32±2.3	15.96±2.0	16.32±2.2	16.67±2.2	17.06±2.3

* DMY – daily milk yield (kg); DFC – daily fat content (%); DPC – daily protein content (%); DLC – daily lactose content (%); DUC – daily urea content (mg/ml); SCC – log transformed somatic cell count

Similarly like in other regions, in Mediterranean region, the highest daily milk production was determined in cows in third parity in both breeds, with higher production in Holsteins. The highest daily fat content (DFC) was observed in first parity Simmentals while the highest value of daily protein content was determined in Simmentals in second parity. Similarly like in other regions, daily urea content was higher in Holsteins comparing to Simmental breed. Also, slightly higher values of somatic cell count were determined in Holsteins.

The variability of microclimate parameters that is ambient temperature, relative humidity and temperature-humidity index (THI)) in the barns accordingly to breed, season and breeding region is presented in the Table 4.

The maximum ambient temperature (T) as well as the highest temperature-humidity index (THI) were recorded in the summer season in the Mediterranean region in the barns where Holstein cows were reared, while the minimum temperature was recorded in the winter season, also in Holsteins' barns but in other region – Eastern. Furthermore, the highest value of relative humidity (RH) was determined in Central region, in Simmentals' barns during the winter season.

Table 4. Variability (mean; SD) of microclimate parameters accordingly to breed, recording season and breeding region

Parameter / Season	Holstein				Simmental			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
	Eastern region							
T	13.42±5.7	23.73±5.8	14.23±6.3	5.72±5.4	12.96±6.1	22.30±5.9	14.12±6.2	6.25±5.0
RH	66.44±12.8	64.18±13.3	67.06±13.9	69.58±14.7	67.90±11.1	67.28±11.4	70.05±10.8	71.31±11.3
THI	56.39±8.4	71.20±8.2	57.38±9.3	44.76±8.4	55.63±9.0	69.37±8.5	57.32±9.3	45.51±7.6
	Central region							
T	15.69±5.8	23.90±5.0	16.20±5.7	9.31±4.5	15.91±5.7	24.05±5.1	16.58±5.6	9.88±4.4
RH	68.12±10.7	69.08±10.9	71.62±10.3	72.84±9.9	69.18±10.3	69.87±10.5	72.52±9.8	73.86±9.5
THI	59.70±8.5	72.00±7.5	60.57±8.6	50.09±7.0	60.03±8.5	72.30±7.6	61.15±8.5	50.91±6.9
	Mediterranean region							
T	14.73±5.0	25.17±4.9	15.70±5.2	9.12±5.1	16.46±4.4	22.43±4.8	16.81±4.5	12.20±3.9
RH	68.75±9.5	70.58±11.1	70.06±8.9	70.73±10.0	70.18±10.6	69.37±11.5	72.26±9.7	71.43±9.9
THI	58.42±5.6	73.99±7.2	59.91±7.9	49.95±7.7	60.97±6.7	69.78±7.0	61.48±6.9	54.59±6.0

* T – ambient temperature (°C); RH – relative humidity; THI – temperature humidity index

Table 5. Correlations between the production traits and microclimate parameters accordingly to breed and breeding region

trait	Holstein						Simmental					
	DMY	DFC	DPC	DLC	DUC	SCC	DMY	DFC	DPC	DLC	DUC	SCC
	Eastern region											
T	-0.032	-0.105	-0.134	-0.019	0.197	0.013	-0.011	-0.123	-0.124	0.0126	0.204	-0.021
RH	0.044	0.040	0.013	-0.017	0.017	-0.222	-0.014	0.010	0.016	-0.024	-0.042	0.034
THI	-0.033	-0.106	-0.133	-0.016	0.195	0.013	-0.011	-0.134	-0.125	0.014	0.205	-0.022
	Central region											
T	-0.012	-0.127	-0.116	-0.016	0.225	-0.004	0.0034	-0.133	-0.129	0.018	0.226	-0.025
RH	-0.039	0.039	0.038	-0.017	-0.013	0.020	-0.019	0.022	0.026	-0.025	-0.032	0.021
THI	-0.012	-0.136	-0.115	-0.016	0.223	-0.004	0.003	-0.133	-0.128	0.018	0.225	-0.025
	Mediterranean region											
T	-0.094	-0.051	-0.073	0.005	0.116	0.003	0.0066	-0.085	-0.112	0.005	0.170	-0.014
RH	-0.065	-0.016	-0.018	0.002	-0.083	0.009	-0.017	-0.001	0.057	0.020	0.101	-0.008
THI	-0.094	-0.053	-0.072	0.007	0.112	0.001	0.066	-0.084	-0.106	0.007	0.177	-0.015

* DMY – daily milk yield (kg); DFC – daily fat content (%); DPC – daily protein content (%); DLC – daily lactose content (%); DUC – daily urea content (mg/ml); SCC – log transformed somatic cell count; T – ambient temperature (^{o}C); RH – relative humidity; THI – temperature humidity index; all correlation coefficients were statistically highly significant (p<0.001)

The correlations between the production traits of dairy cows (daily milk yield, daily fat, protein lactose and urea content and somatic cell count) and the microclimate parameters (ambient temperature, relative humidity and temperature-humidity index – THI) in the barns accordingly to the breed and breeding region are presented in the Table 5. All determined correlation coefficients were statistically highly significant ($p < 0.001$). A negative effect of increased ambient temperature on daily milk yield (DMY) and daily fat, protein and lactose content (DFC, DPC and DLC) was determined in both breeds in all analysed regions. The most pronounced negative effect of increased ambient temperature of DMY in Holsteins was determined in Mediterranean region, while in Simmental breed the highest drop in daily milk production was observed in Central region. The negative effect of high relative humidity in the barns was observed in Holsteins reared in Central and Mediterranean region, as well as in Simmentals reared in Central region. The increase of temperature-humidity index resulted in decrease of daily milk yield, and high variability in daily compositions in both breeds in all analysed regions.

Discussion

Performed analysis indicate high variability of production traits due to cow's breed, parity as well as breeding region. Also, high variability of microclimate parameters in the barns due to season and breeding region was found. Furthermore, statistically highly significant ($p<0.001$) correlations between the production traits and microclimate parameters were determined. Finally, the negative effect of inadequate microclimate on daily milk production was determined in both breeds in all breeding regions.

Accordingly, to *Kadzere et al. (2002)* the intensive genetic selection for high milk production resulted in changes in the thermoregulation physiology of dairy cattle. Larger frames and larger gastrointestinal tracts in high production animals enable them to digest more feed, but also creates more metabolic heat and reduces the animal's ability to regulate temperature heat stress environment meaning that increased milk yield, feed intake and metabolic heat the thermo-neutrality to lower temperatures. Furthermore, highly productive dairy cattle lose their ability to regulate body temperature at an air temperature of only 25 to 29°C. For example, *Berman (2005)* notified that increasing of daily production from 35 to 45 kg results in a higher sensitivity to thermal stress and reduces the threshold temperature for intermediate heat stress by 5°C. *Gantner et al. (2011)* pointed out that even in periods with lower temperatures when problems could be caused by high relative humidity, the heat stress condition may occur. *Du Preez et al. (1990a)* determined in dairy cows reared in South Africa, the decrease of milk yield at THI higher than 72 (22°C at 100% RH, 25°C at 50% RH, or 28°C at 20% RH). *Casa and Ravelo*

(2003) also determined significant decrease in milk production, in amount of 6% (9%) depending on the region, during the warmer months in Argentina. *Bouraoui et al. (2002)* reported decrease of 0.41 kg of milk / day for each point increase of THI above 69. The threshold value of THI depend on a many effects, for instance, lactation stage, parity, level of milk production, breed, breeding region, individual susceptibility to heat stress, etc. *(Kadzere et al. 2002, Bohmanova 2006, Collier et al. 2006, Hansen 2013, Gantner et al. 2017)*. For example, *Bouraoui et al. (2002)* put the threshold on 65-69, *Bernabucci et al. (2010)* as well as *Collier and Hall (2012)* on 68, *Du Preez et al. (1990a, b)* on 72, while *Bohmanova et al. (2007)* depending on region defined threshold THI value 72 in Georgia, and 74 in Arizona. *West (2003)* determined a reduction in DMI by 0.85 kg with every 1°C rise in air temperature above a cow's thermoneutral zone, therefore this decrease in intake accounts approximately 36% of the decrease in milk production. *Spiers et al. (2004)* notified that milk yield decreases by 0.41 kg/cow/day for each THI unit increase of above 69, within a day after initiation of heat stress, feed intake decreased, while after 2 days of HS milk yield decreased. *Gaafar et al. (2011)* determined that increasing of THI in the winter season from 59.82 to 78.53 in the summer season, HS reduced total (305 days) and daily milk yield by 39.00%, 31.40% and 29.84%, relatively. According to *Baumgard and Rhoads (2013)*, drop in milk production up to 50% in dairy animals might be due to reduced feed intake. *Lambertz et al. (2014)* pointed out that the difference in defined threshold values could be due to better adapted cows, farm management or housing.

Conclusion

Based on the conducted research, the negative effect of the increase of microclimate parameters on daily milk production in all cows regardless the breed and breeding region could be pointed out. Also, variability in daily production traits due to cow's breed, parity as well as breeding region as well as variability of microclimate parameters in the barns due to season and breeding region was found. Since genetic evaluation and selection of dairy cattle for heat resistance is only long-term method for heat stress managing, determined effect will be taken into account in the statistical model for estimation of genetic parameters and breeding values for heat resistance in dairy cattle.

Analiza proizvodnih karakteristika i mikroklimatskih parametara na farmama za proizvodnju mleka

Goran Vučković, Tina Bobić, Pero Mijić, Mirna Gavran, Klemen Potočnik, Vladan Bogdanović, Vesna Gantner

Rezime

Cilj istraživanja je bio određivanje varijabilnosti proizvodnih osobina (dnevni prinos i sastav mleka) i mikroklimatskih parametara (temperatura i vlažnost okoline) u objektima za držanje krava za proizvodnju mleka; kao i korelacija između analiziranih grupa osobina; 1.636.192 zapisa za grla simentalske rase i 1.275.713 zapisa test dana grla holštajn rase. Izvršene analize pokazuju veliku varijabilnost proizvodnih osobina zbog rase krava, pariteta kao i odgajivačkog regiona. Takođe je utvrđena velika varijabilnost mikroklimatskih parametara u objektima zbog sezone i odgajivačkog regiona. Pored toga, utvrđene su statistički vrlo značajne ($p<0,001$) korelacije između proizvodnih svojstava i parametara mikroklime. Konačno, negativan uticaj neadekvatne mikroklime na svakodnevnu proizvodnju mleka utvrđen je kod obe rase u svim odgajivačkim regionima. Pošto je genetska procena i selekcija mlečnih goveda na otpornost na visoke temperature sredine samo dugoročna metoda za upravljanje toplotnim stresom, utvrđeni efekat biće uzet u obzir u statističkom modelu za procenu genetskih parametara i odgajivačkih vrednosti.

Ključne reči: proizvodne osobine, mlečne krave, parametri mikroklime

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