Acta fytotechn zootechn, 24, 2021(Monothematic Issue: Problems and Risks in Animal Production): 85–88
http://www.acta.fapz.uniag.sk

Original Paper

Dependence of milk production of dairy sheep on climate conditions

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Article Details: Received: 2020-10-14 | Accepted: 2020-11-27 | Available online: 2021-01-31

https://doi.org/10.15414/afz.2021.24.mi-prap.85-88

The aim of the study was to determine the influence of selected climatic characteristics on the milk production of ewes during lactation. Data of ewes from sheep farm Liptovská Teplička located in moderate climate zone (latitude 48° 57′ 50.3“ N, longitude 20° 04′ 31.0“ E) were analysed. In period from 2017 to 2019, the following milk traits: total morning milk production (TMPM), total evening milk production (TMPE), total morning + evening production (TMPM + E) and average daily milk production per ewe (ADMP) were measured on a daily basis. Traditional (Carpatian) production system was applied: ewes were on pasture and machine milked twice a day. Climate characteristics were monitored in 10-minute intervals by standard weather station (supplier: firm PHYSICUS), located near sheep farm. The influence of air temperature – *T* (°C), of relative humidity – RH (%), of wind speed (m/s) and of total precipitation (mm) recorded daily between 5 a.m. and 4 p.m. in period from April to September on milk traits was analysed. Temperature-humidity index (THI) was calculated according to National Research formula. The influence of year, of month and of interaction year x month was also analysed. Covariance analysis and Pearson correlation coefficients using statistical programme SASv9.2 (procedures GLM and CORR) were employed. The influence of month and of interaction year x month, respectively, on milk traits was found (P <0.001). Temperature significantly influenced TMPM + E (P <0.01) and ADMP (P <0.05). The remaining climate characteristics, mainly wind speed and RH had not significant influence on milk traits. Heat-humidity index significantly influenced TMPM (P <0.001) and ADMP (P <0.01), respectively. Residual correlation between ADMP and THI was -0.166 (P <0.001). Three of four milk traits of ewes assigned to group cold stress (THI <40.0) were significantly lower (P <0.05) than respective milk traits of ewes milked in days without heat or cold stress (THI >40.0 and THI <= 68.0). Preliminary results suggest that milk production traits of dairy sheep may be significantly influenced by climate also in moderate climatic zone.

Keywords: sheep, thermal stress, milk yield, temperate zone

1 Introduction

There was proofed that in countries of moderate climate zone livestock production is changing due to global warming (Gauly et al., 2013; Gauly and Ammer, 2020). This seems to be reason for occurrence of uncommon daily temperatures and frequent season changes. Number of days in those heat-humidity index (THI) is higher than maximum value specified for wellbeing of livestock animals in European countries of moderate climate zone (above 68) has been increasing (Silanikove, Koluman-Darcan, 2015). Therefore, the influence of climate changes (mainly of heat stress) on milk production traits of dairy sheep and goats has become the object of interest to a greater extent recently (Finocchiaro et al., 2005; Marai et al., 2007; Hamzaoui et al., 2013; Salama et al., 2014; Dawood, 2017). The influence of cold stress on ewe performance occurred was shown less frequently (Ramón et al., 2016). It has been observed that breeding aimed at selection of animals resistant to climate change and/or adaptable to climate change is of an increasing importance (Ramón et al., 2016; Sánches-Molano et al., 2019). Flock management needs to be oriented in regulations aimed at minimizing of heat and/or cold stress on livestock production (Ramón et al., 2016; Gauly, Ammer, 2020). The objective of the study was to analyse influence of fixed factors (year, month and interaction year x month)

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as well as influence of climate characteristics (temperature, relative humidity, total precipitation, wind speed and, mainly, THI) on milk production traits..

2 Material and methods

2.1 Biological data

The experiment was done on sheep farm Liptovská Teplička (coordinates: latitude 48° 57′ 50.3″ N and longitude 20° 04′ 31.0″ E), where dairy sheep of purebred Improved Valachian (IV) and crosses IV × LC (Lacaune) were kept. In period from 2017 to 2019, total morning milk production (TMPM), total evening milk production (TMPE), and total morning/evening milk production (TMPM + E) were measured. Number of ewes milked was also recorded on a daily basis and used for analyses of average daily milk production per ewe (ADMP). Traditionally, ewes are milked from March to October. Milking of ewes commonly depends on length of lambing season and on climate conditions. Only milk production over April to September was analysed in the present study (no all ewes were milked in March and October each year). Number of days in milk (in 2017 and 2018) was 183, whereas number of days in milk (in 2019) was 173 due to fact that milking started on April 11.

2.2 Selected climate characteristics

Climate characteristics were monitored by weather station of Slovak Academy of Sciences (supplier: firm PHYSICUS) located about 2.5 km from sheep farm in period from 2017 to 2019. Data were recorded in 10-minute intervals. Average daily values of the following climate characteristics: air temperature – *T* (°C), relative humidity – RH (%), wind speed – WS (v m/s) and total precipitation – TP (mm) measured between 5 a.m. and 4 p.m. daily from April to September were used. This period was chosen due to fact that ewes were moved outside of stable (on pasture) after morning milking. Temperature-humidity index (THI) was calculated according to National Research formula (NRC, 1971), which is widely considered in countries of moderate climate zone (Gauly, Ammer, 2020).

2.3 Statistical analysis

Covariance analysis was used to analyse the influence of selected climate characteristics on TMPM, TMPE, TMPM + E and ADMP. The following fixed factors: year (2017, 2018, 2019), month (April, May, June, July, August, September) and interacion year × month, and covariates: air temperature, total precipitation, wind speed, relative humidity and THI index (instead of T and RH). Pearson coefficients were used to assess phenotype and residual correlations between milk traists and climate characteristics (data measured in same days). Residual correlations were assessed from estimates of residua provided by covariance analysis. Statistical program SASv9.2 (procedures GLM and CORR) were employed. Scheffe multiple-range tests were used to asses significance of differences between individual levels of analysed fixed effects: $P<0.05$ (+), $P<0.01$ (++), $P<0.001$ (+++).

3 Results and discussion

Basic statistics of milk production traits and selected climate characteristics are given in Table 1. In analysed population, which ranged from 138 to 429 heads, ADMP per ewe was equal to 0.487 l, in best days with milk production above 700 ml occurred. These values agreed with milk production data published for Improved Valachian breed (Breeding Services of SR). Wide ranges between minimal and maximal values of selected climate characteristics were found. For instance, extremly low temperatures (under 0 °C) and high temperatures (up to 27 °C) were recorded. On average, relative humidity was above 95%, total precipitation and wind speed were 1.55 mm and 1.77 m/s (Table 1), respectively.

Covariance analysis of milk traits which included four climate characteristics: T, RH, WS, TP, showed that month had highest importance ($P<0.001$). The interaction year x month also had highly significant influence ($P<0.001$). When ADMP estimated for same months across respective years was compared, significant differences between April 2017 (0.607 l), April 2018 (0.553 l) and April 2019 (0.438 l) were found, for example. Similarlly, significant differences in ADMP between May months and September months across respective years were also found. Temperature had significant influence on TMPM + E ($P<0.01$) and ADMP ($P<0.05$), respectively. Wind speed and RH had not significant influence on milk traits, total precipitation had significant influence on TMPM ($P<0.05$).

Table 1 Basic statistics for total milk productions and average daily milk production per ewe and selected climate characteristics

Trait/characteristics	Number of analysed days in milk	Mean ±*SD*	Minimum	Maximum
Heads of ewes	539	336.9 ±84.27	138	429
TMPM (1) (l)	539	90.3 ±2 6.62	0	143.0
TMPE (2) (l)	539	74.3 ±25.10	0	131.0
TMPM + E (3) (l)	539	164.6 ±50.73	19.0	259.0
ADMP(4) (l)	539	0.487 ±0.093	0.14	0.76
Temperature – *T* (°C)	539	14.9 ±5.58	-2.78	26.72
Relative humidity – RH (%)	539	70.9 ±12.17	33.84	95.51
THI5	539	58.4 ±8.52	29.32	74.13
Total precipitation – TP (mm)	539	1.55 ±3.91	0	34.60
Wind speed – WS (m/s)	539	1.77 ±0.632	0.58	4.00

1, 2, 3 – total milk production (morning, evening and morning + evening, l), 4 – average daily milk production per ewe (l); the same explanation for Tables 2 and 3; THI5 – temperature-humidity index according to NRC (1971)

Alternative covariance analysis, which considered three climate characteristics: THI, total precipitation and wind speed (Table 2), showed highest significant influence of THI mainly on TMPM (*P* <0.001) and ADMP (*P* <0.01), respectively. Total precipitation had important influence on TMPM (*P* <0.01) and TPMM + E (*P* <0.05), respectively. Wind speed did not show significant influence on milk traits. Coefficients of determination (R^2) were high, i.e. between 0.675 and 0.878. Taking into account fixed effects (year, month, interaction year x month), residual correlation between ADMP and THI was equal to -0.166 (*P* <0.001), i.e. ADMP was decreasing along with increasing THI. Finocchiaro et al. (2005) found that in dairy sheep in the Mediterranean region, daily milk and also fat-plus protein yield decreased with increasing THI index. When relationship between ADMP on one hand and T, TP, RH, WS on the other hand was analysed, residual correlation was equal to +0.133 (*P* <0.01) between ADMP and T, and equal to -0.091 (*P* <0.05) between ADMP and RH, respectively. These findings indicated that relationships between milk production and climate characteristics may not be linear. Similarly to study of Ramón et al. (2016), climate characteristics highly influenced milk production on respective day of measuerement or day before day of measurement.

Table 2 Covariance analysis of milk production of dairy sheep

Trait	R^2	F-value					
		year (Y)	month (M)	interaction Y × M	THI	TP	wind speed
TMPM (l)	0.838	15.22+++	451.83+++	35.77+++	11.14+++	6.88++	0.69 ns
TMPE (l)	0.865	0.33ns	571.12+++	41.33+++	4.22+	2.33 ns	0.65 ns
TMPM + E (l)	0.878	6.06++	637.61+++	47.51+++	9.51++	5.66+	0.01 ns
ADMP (l)	0.675	71.50+++	113.88+++	25.29+++	9.40++	0.33 ns	0.32 ns

When days in milk were assigned to three groups according to THI values (Table 3), milk production of ewes assigned to group cold stress was significatly lower in three of four analysed climate characteristics (*P* <0.05) than milk production of ewes milked on days without heat stress, i.e. during temperature neutral zone (THI >40.0 and THI <= 68.0). Between ewes assigned to group medium heat stress and to group without heat stress, the only difference in TMPE was found significant (*P* <0.05). No days with THI >75.0 occurred. Similarly, Ramón et al. (2016) reported a higher decrease of milk production due to cold stress than due to heat stress.

Table 3 Total and average daily milk yield of ewes assigned to groups according to temperature humidity index.

Group	*n*	TMPM (l)	TMPE (l)	TMPM + E (l)	ADMP (ml)
Ccolds	22	81.3 ±2.58^{a}	73.5 ±2.22^{ab}	154.9 ±4.28^{a}	0.446 ±0.013^{a}
whs	462	90.7 ±0.52^{b}	74.6 ±0.44^{a}	165.2 ±0.859^{b}	0.489 ±0.003^{b}
mhs	55	89.1 ±1.63^{b}	71.4 ±1.40^{b}	160.5 ±2.70^{ab}	0.476 ±0.008^{ab}

n = number of analysed days; cold stress (colds): THI <= 40.0; without heat stress (whs): THI >40.0 a THI <= 68.0; medium heat stress (mhs): THI >68.0 a THI <= 75.0; a,b – values within the same column with different superscript letters differ significantly at P <0.05; TMPM + E – whs:mhs P = 0.0975

4 Conclusions

The results of this study show that milk production traits of dairy sheep may be significantly influenced by climate also in moderate climatic zone. In analysed population, the higher influence of cold stress than that of heat stress was found. However, ewes mostly produced milk without cold stress and/or without heat stress (86% of days in milk). Milk production in days of medium heat stress was only slightly lower than in days of without heat stress. From aspect of ewe wellbeing, minimizing of both cold stress and heat stress is needed.

Acknowledgments

The present study was supported by Grant of Ministry of Education, Science, Research and Sport of the Slovak Republic (KEGA No. 015SPU-4/2019).

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