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INFLUENCE OF WEATHER CONDITIONS IN THE COLD PERIOD OF YEAR ON THE MICROCLIMATE IN COWSHEDS AND MILK PRODUCTIVITY OF COWS

Volodymyr SHABLIA[1], Victoria KUNETS[2], Tetiana DANILOVA[1], Petro SHABLIA[2]

[1]State Biotechnological University, 44 Alchevskikh Str., Kharkiv, Ukraine
[2]Institute of Pig Breeding and Agricultural Production of the National Academy of Agrarian Sciences of Ukraine, 1 Swedish Grave Str., Poltava, Ukraine

Corresponding author email: shabliavladimir@gmail.com

Abstract

The influence of weather conditions during the cold period of year on microclimate parameters of cowsheds and on the milk productivity of cows kept in traditional tethered conditions in typical brick cowsheds with natural ventilation was determined. It was established that in the conditions of Ukraine the temperature in cowsheds during the cold period of the year significantly depends on: the number of cows in them ($r = 0.509$; $p = 0.018$); the number of livestock per unit volume of the cowshed ($r = 0.68$; $p = 0.001$); the area of ventilation holes ($r = 0.745$; $p<0.001$). The humidity inside the cowsheds is most dependent on the outdoors air humidity ($r = 0.514$; $p = 0.017$), as well as on the number of cows per unit volume of the cowshed ($r = 0.533$; $p = 0.013$). In the cold period of the year the most problematic from the point of view of comfort for animals are periods of severe frosts. When cows were kept on a tether in typical brick cowsheds with natural ventilation and walking areas, the correlation coefficients between gross milk yield and: the average temperature outdoors were in the range of r = 0.625...0.636 ($p<0.001$); atmospheric pressure – r = –0.237...–0.276 ($p\leq0.001$). A significant synchronicity of fluctuations in time of outdoor air temperature indicators and average milk yield per cow was established at periods of severe frosts: the decrease in daily milk yield due to frost reached 0.8 ... 2.2 kg per day (up to 21%). Cluster analysis established that for the synchronous distribution of days of the cold period into groups (clusters) based on the average outdoors night air temperature (tv) and gross milk yield (valmol), it is expedient to distribute the sample into 3 gradations.

Key words: *cow, cowshed, cold weather, microclimate, milk yield.*

INTRODUCTION

The influence of microclimate indicators on the condition of animals and their productivity is different (Kucevic et al., 2013).

The practice of animal husbandry in Ukraine has shown that of all microclimate indicators, air temperature has the greatest effect on animal productivity (Shablia et al., 2015).

Despite the fact that the thermoneutral zone for cattle is quite wide, for a highly productive herd creating an optimal environment including air temperature is very important.

This is due to the fact that intensive exploitation of animals requires maximum body tension. And this affects their resistance, health and productivity. This applies to both warm (Michael et al., 2023; Polsky & von Keyserlingk, 2017) and cold (Song et al., 2023; Angrecka et al., 2020; Ahmed et al., 2022) periods of the year.

Next in importance for maintaining an optimal microclimate are indicators of humidity (Xiong Yan et al., 2017; Havelka et al., 2022) and the content of harmful gases in the air (Mazur et al., 2021).

Regulation of the microclimate in livestock premises is one of the important links in the technology of industrial milk production. This is possible if the construction solutions of livestock premises involve the use of effective ventilation systems and building materials that correspond to the climatic zones (Picuno, 2016).

Farmers must provide such zoohygienic parameters of the microclimate that would fully meet the physiological needs of the body and ensure good health of animals (Assatbayeva et al., 2022).

A comfortable indoor microclimate promotes effective heat exchange, quick adaptation, and prevention of animal diseases. It makes it possible to increase natural resistance, ensure high reproductive capacity, reduce feed and energy costs, as well as obtain a genetically determined amount of high-quality products from animals.

According to Samarin (2000), the productivity of animals is determined by 10-30% by the microclimate in livestock premises and the conditions of keeping. In particular, the deviation of the microclimate parameters from the optimal limits can lead to a decrease in milk yield by 10-20%, a decrease in live weight gain - by 20-35%, an increase in the death of young animals - by 5-40%, a decrease in the resistance of animals to diseases.

Creating and maintaining an optimal microclimate is also associated with extending the service life of buildings and the equipment installed in them (Skliar et al., 2023), decrease in the cost of additional feed as well as positive affects service personnel.

The analysis of literary sources shows that cowshed ventilation systems with natural excitation of air movement are currently the most widely used in cattle breeding (Kavolelis et al., 2008; Wójcik et al., 2017; Ogink et al., 2013; Nieckarz et al., 2023). This is explained by the fact that such systems are independent of energy sources and have high reliability.

However, under such ventilation system the microclimate and therefore the dairy productivity of cows can be largely determined by the influence of weather factors (Hill & Wall, 2015; Głuskia et al., 2014).

The purpose of the research is to determine the influence of the weather conditions in the cold period of the year on the parameters of microclimate in typical brick cowsheds with natural ventilation and on the milk productivity of cows kept in traditional tethered housing.

MATERIALS AND METHODS

The material for the research was information on the main characteristics of the weather that took place in the conditions of the farm "Gontarivka" (Kharkiv region, Ukraine) in the cold period of the year (the period from October to April lasting 195 days), when the average daily air temperature outside was in the range of +10ºC to –26ºC).

Thus, air temperature, relative air humidity, speed of air movement outdoors, atmospheric pressure, wind direction, cloud cover, and amount of precipitation were taken into account. These meteorological indicators can potentially affect the indoor microclimate and animal comfort, and therefore milk production.

At the same time, the collection of information on the volumetric and planning characteristics of 6 cowsheds of different sizes was carried out. In particular, the length, width, height of the cowsheds (m), their volume (m^3), the total area of open ventilation holes, the number of cows and other indicators were measured. The features of cowsheds and applied technologies are determined.

All cowsheds were built of brick and had a natural ventilation system. Cows were kept on a leash in all cowsheds. From 100 to 200 cows were kept in various cowsheds.

The parameters of the microclimate inside the cowsheds were recorded, as well as the dynamics of milk yield, fat and protein content in milk during the same period in two branches of the farm "Gontarivka" – "Central" (3 cowsheds) and "Profintern" (3 cowsheds).

Databases have been created, which include the above indicators characterizing milk productivity, microclimate of cowsheds, technology characteristics and weather.

The relationship between the main indicators of weather conditions, the microclimate of cowsheds and milk productivity were evaluated by correlation analysis. Regularities of influence of weather conditions on milk productivity were additionally studied using cluster analysis.

RESULTS AND DISCUSSIONS

The results of the conducted research show that the microclimate of cowsheds in the cold period of the year is formed to a large extent under the influence of weather conditions. It was established that the correlations between the air temperature outdoors and the temperature inside different cowsheds was at the level of $r = 0.80$ ... 0.94 ($p = 0.029$ ... 0.002).

Among other studied factors, the temperature in the cowsheds depended most on: the number of cows kept in the cowshed ($r = 0.509$; $p = 0.018$); the number of cows per unit volume of the cowshed ($r = 0.680$; $p = 0.001$); the area of open ventilation holes ($r = 0.745$; $p<0.001$).

The relative humidity of the air inside the cowsheds was most dependent on the outdoor air humidity (r = 0.514; p = 0.017), as well as on the number of cows per unit volume of the cowshed (r = 0.533; p = 0.013). Thus, our research supports the claims of Głuskia et al. (2014) and Hill & Wall (2015) about the significant direct influence of weather conditions on microclimate parameters (such as temperature and air humidity inside cowsheds when using natural ventilation). In our studies, this influence refers to the cold period of the year.

As a result of the listed factors, the winter temperature in the cowshed with the lowest number (density) of cows per unit volume of the cowshed periodically dropped below 0ºC. This happened mostly when the air temperature outside was below –12ºC. The result was freezing of the water in drinking troughs, uncomfortable conditions for animals and workers (temperature outside the comfort zone).

In the autumn and spring periods, the temperature indicators were closer to the optimal level, which is largely due to more accepted indicators of the outdoors temperature and greater possibilities of regulating the intensity of ventilation. Humidity indicators during these seasons slightly exceeded the normative due to high humidity values outside.

It was established that in the cold period of the year (lasting 195 days), the correlation coefficients (Tables 1, 2) between the gross milk yield on the farm and: the average day and night air temperature outdoors were within r = 0.625 ... 0.636 (p < 0.001); atmospheric pressure - r = –0.237 ... –0.276 (p ≤ 0.001). The significant correlation coefficients obtained by us testify to the correctness of the conclusions of Angrecka et al. (2020), Ahmed et al. (2022) and Song et al. (2023) regarding the considerable influence of the microclimate in the cold period of the year on animal productivity. And the data on the maximum correlations of milk productivity with air temperature are consistent with the statement of Shablia et al. (2015) on air temperature as the most influential indicator of microclimate.

Table 1. Correlation coefficients between the characteristics of night weather conditions in the cold period of the year (lasting 195 days) and indicators of morning milk productivity of cows at the "Profintern" branch

Characteristics	Gross milk yield, kg	Milk fat content, %	Milk protein content, %	Average air temperature, ºC (tv)	Minimum air temperature, ºC	Maximum air temperature, ºC	Atmospheric pressure, mm Hg	Relative air humidity, %	Speed of air movement, m/s	Cloudiness, %	Amount of precipitation, mm
Gross milk yield, kg	1	0.479**	0.107	0.636**	0.609**	0.711**	-0.276**	-0.178*	-0.070	-0.016	0.085
Milk fat content, %	0.479**	1	0.195**	0.205**	0.217**	0.282**	-0.079	-0.199**	-0.031	-0.124	0.043
Milk protein content, %	0.107	0.195**	1	0.064	0.046	0.098	-0.164*	-0.198**	-0.006	0.067	0.052
Average air temperature, ºC (tv)	0.636**	0.205**	0.064	1	0.992**	0.970**	-0.471**	0.228**	-0.105	0.277**	0.162*
Minimum air temperature, ºC	0.609**	0.217**	0.046	0.992**	1	0.950**	-0.460**	0.268**	-0.091	0.327**	0.166*
Maximum air temperature, ºC	0.711**	0.282**	0.098	0.970**	0.950**	1	-0.450**	0.133	-0.117	0.180*	0.156*
Atmospheric pressure, mm Hg	-0.276**	-0.079	-0.164*	-0.471**	-0.460**	-0.450**	1	-0.126	-0.256**	-0.271**	-0.369**
Relative air humidity, %	-0.178*	-0.199**	-0.198**	0.228**	0.268**	0.133	-0.126	1	-0.146*	0.308**	0.185**
Speed of air movement, m/s	-0.070	-0.031	-0.006	-0.105	-0.091	-0.117	-0.256**	-0.146*	1	0.086	0.141*
Cloudiness, %	-0.016	-0.124	0.067	0.277**	0.327**	0.180*	-0.271**	0.308**	0.086	1	0.112
Amount of precipitation, mm	0.085	0.043	0.052	0.162*	0.166*	0.156*	-0.369**	0.185**	0.141*	0.112	1

Notes. * – significance level of correlation coefficient P≤0.05; ** – significance level of correlation coefficient P≤0.01.

In the coldest period of winter which took place in January-February 2014 (lasting 31 days), correlations between indicators of milk productivity and weather were mostly slightly smaller than when taking into account the entire cold period, but mostly statistically significant.

Extreme deviations of the air temperature from the norm in the coldest period have a particularly strong effect on the productivity of animals. Thus, the decrease in milk yield due to severe frosts (with unchanged feeding) was of the order of 0.8 - 2.2 kg per cow per day or up to 21% (Figures 1, 2). The detected level of decrease in milk productivity of cows generally corresponds to the 10-20% decrease in milk yield indicated by Samarin (2000). The reason of both is the deterioration of the microclimate.

It should be noted that after the warming there was no recovery of milk productivity to the level of indicators that occurred before severe frosts at the branches of the farm "Gontarivka".

Table 2. Correlation coefficients between the characteristics of night weather conditions in the cold period of the year (lasting 195 days) and indicators of morning milk productivity of cows at the "Central" branch

Characteristics	Gross milk yield, kg	Milk fat content, %	Milk protein content, %	Average air temperature, ºC (tv)	Minimum air temperature, ºC	Maximum air temperature, ºC	Atmospheric pressure, mm Hg	Relative air humidity, %	Speed of air movement, m/s	Cloudiness, %	Amount of precipitation, mm
Gross milk yield, kg	1	-0.388*	0.087	0.401*	0.369*	0.430*	-0.575**	0.470**	-0.146	0.349	0.279
Milk fat content, %	-0.388*	1	0.037	-0.288	-0.273	-0.291	0.374*	-0.343	0.236	-0.024	-0.080
Milk protein content, %	0.087	0.037	1	-0.597**	-0.591**	-0.599**	0.179	-0.524**	0.490**	-0.013	-0.048
Average air temperature, ºC (tv)	0.401*	-0.288	-0.597**	1	0.996**	0.995**	-0.777**	0.865**	-0.293	0.390*	0.387*
Minimum air temperature, ºC	0.369*	-0.273	-0.591**	0.996**	1	0.983**	-0.771**	0.854**	-0.255	0.387*	0.412*
Maximum air temperature, ºC	0.430*	-0.291	-0.599**	0.995**	0.983**	1	-0.783**	0.877**	-0.323	0.398*	0.366*
Atmospheric pressure, mm Hg	-0.575**	0.374*	0.179	-0.777**	-0.771**	-0.783**	1	-0.819**	0.082	-0.509**	-0.356*
Relative air humidity, %	0.470**	-0.343	-0.524**	0.865**	0.854**	0.877**	-0.819**	1	-0.401*	0.287	0.359*
Speed of air movement, m/s	-0.146	0.236	0.490**	-0.293	-0.255	-0.323	0.082	-0.401*	1	0.083	0.128
Cloudiness, %	0.349	-0.024	-0.013	0.390*	0.387*	0.398*	-0.509**	0.287	0.083	1	0.025
Amount of precipitation, mm	0.279	-0.080	-0.048	0.387*	0.412*	0.366*	-0.356*	0.359*	0.128	0.025	1

Notes. * – significance level of correlation coefficient P≤0.05; ** – significance level of correlation coefficient P≤0.01.

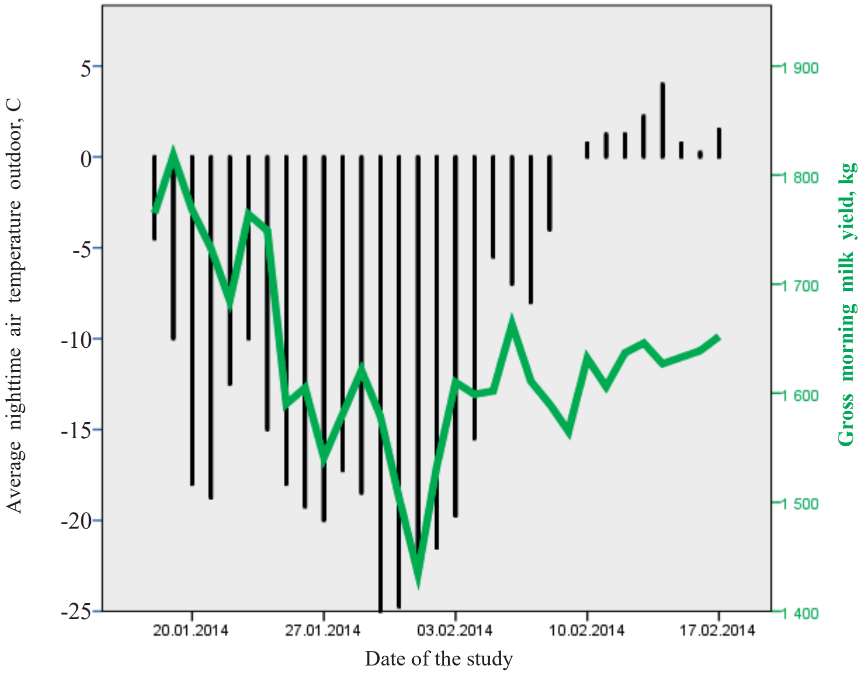

Figure 1. Dynamics of changes in time of the average nighttime temperature outdoor (left scale, columns) and gross morning milk yield (right scale, curve) during the coldest period of the year at the "Profintern" branch

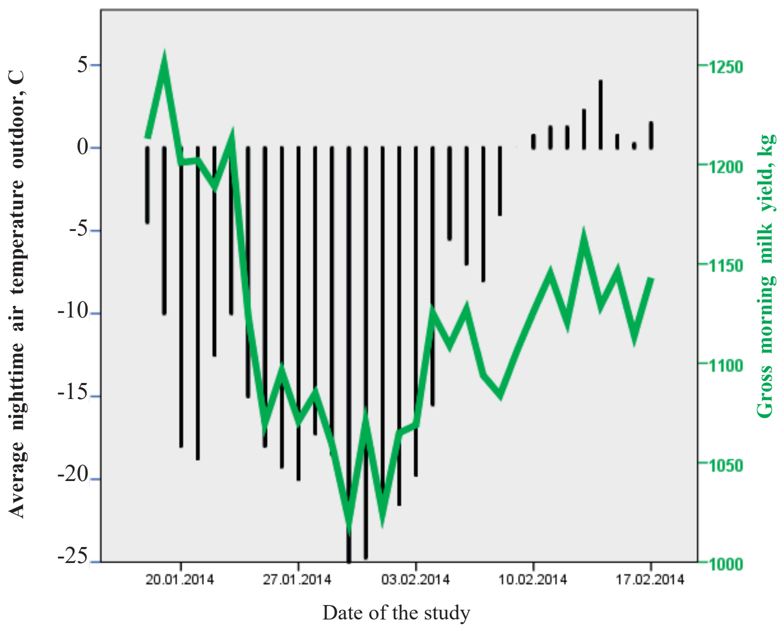

Figure 2. Dynamics of changes in time of the average nighttime temperature outdoor (left scale, columns) and gross morning milk yield (right scale, curve) in the coldest period of the year at the "Central" branch

Cluster analysis established that in order to synchronously distribute the days of the cold period of the year into groups (clusters) based on the average outdoor night air temperature (tv) and gross milk yield at the branch (valmol), it is expedient to distribute the sample into 2-3 gradations.

In particular, at the "Profintern" branch (Figure 3), the centers of three temperature gradations were: tv_1 = +6.11°C, tv_2 = –0.55°C and tv_3 = –19.07°C; and the corresponding average gross milk yields were: $valmol_1$ = 2276 kg, $valmol_2$ = 1883 kg and $valmol_3$ = 1609 kg. At the "Central" branch, the centers of the two temperature gradations were: tv_1 = 2.38°C and tv_2 = –16.50°C; and the corresponding average gross milk yield were: $valmol_1$ = 1478 kg and $valmol_2$ = 1150 kg. The differences between the gross milk yields of the groups (clusters) extreme in terms of outdoor temperature (t_1 and t_2 for the "Central" branch; t_1 and t_3 for the "Profintern" branch) were 328–667 kg ($p<0.001$). These results confirm the correctness of the statement of Shablia et al. (2015) that the negative influence of microclimate parameters on milk production of cows is observed during periods of long maximum deviations of these parameters from optimal values.

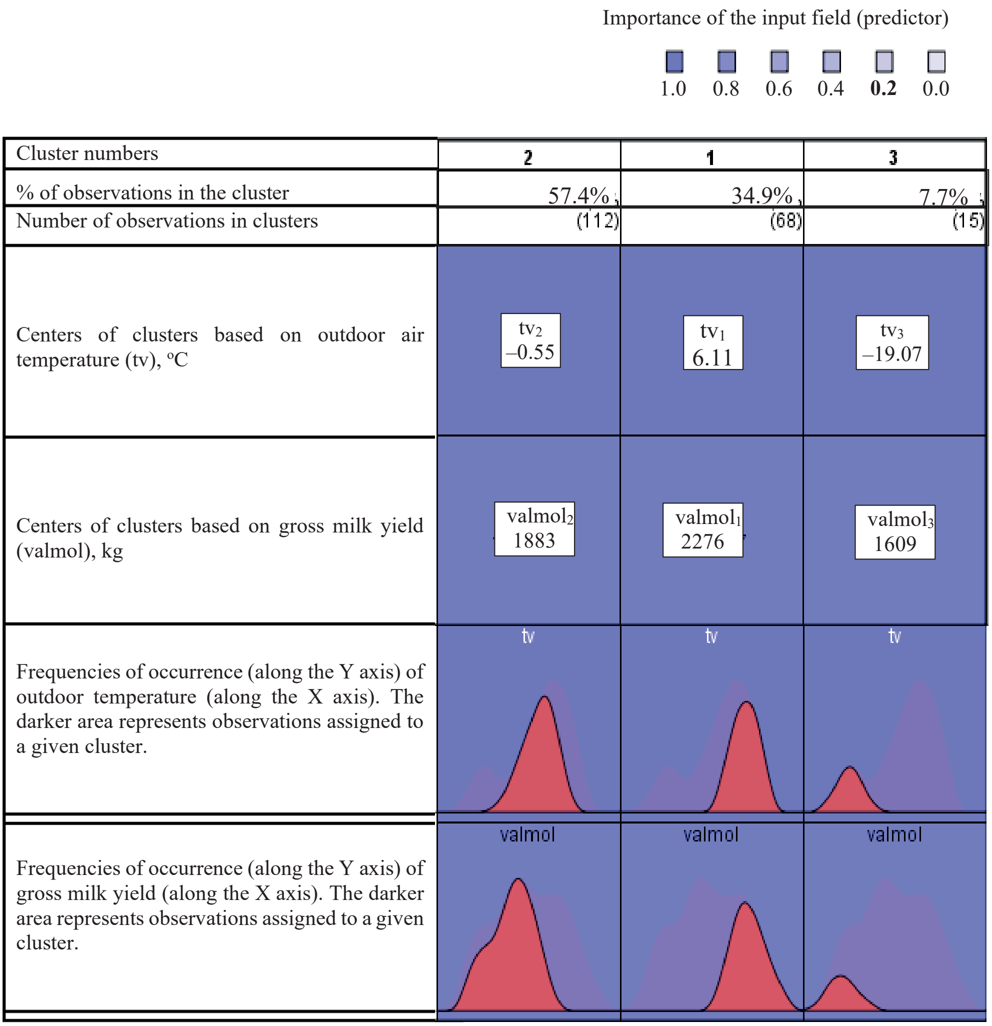

Figure 3. Results of cluster analysis of average nighttime outdoor temperature (tv) and gross milk yield (valmol) during the cold period at the "Profintern" branch

CONCLUSIONS

1. The temperature in the cowsheds during the cold period of the year significantly depends on: the number of cows in it (r = 0.509; p = 0.018); the number of cows per unit volume of the cowsheds (r = 0.68; p = 0.001); the area of ventilation holes (r = 0.745; p<0.001).
2. The humidity inside the cowsheds is mostly dependent on the outdoors air humidity (r = 0.514; p = 0.017), as well as on the number of cows per unit volume of the cowshed (r = 0.533; p = 0.013).
3. In the cold period of the year, the most problematic from the point of view of comfort for animals are periods of severe frosts. When cows were kept on a tether in typical brick cowsheds with natural ventilation and walking areas, the correlation coefficients between gross milk yield and: the average temperature outside were in the range of r = 0.625 ... 0.636 (p<0.001); atmospheric pressure – r = –0.237 ... –0.276 (p≤0.001).
4. A significant synchronicity of fluctuations in time of outdoor air temperature indicators and average milk yield per cow was established at periods of severe frosts: the decrease in daily milk yield due to severe frost reached 0.8 ... 2.2 kg per day (up to 21%).
5. Cluster analysis established that for the synchronous distribution of days in the cold period into groups (clusters) at the same time according to the average outdoors night air temperature (tv) and gross milk yield (valmol), it is more expedient to distribute the sample into 3 gradations. The centers of temperature gradations are tv1 = +6.11ºC, tv2 = –0.55ºC and tv3 = –19.07ºC. And the corresponding average gross milk yield are valmol1 = 2276 kg, valmol2 = 1883 kg and valmol3 = 1609 kg . The difference between extreme groups by outdoors temperature were 667 kg of gross milk yields (p < 0.001).

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