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Influence of microclimate on ketosis, mastitis and diseases of cow reproductive organs

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Abstract This study investigated the influence of the farm microclimate parameters in different seasons on the incidence of ketosis, foot diseases, reproductive diseases, and mastitis in three dairy farms of North Kazakhstan. Microclimate parameters were recorded in four seasons: summer, autumn, winter, and spring. The average temperature was 1.2 °C above the established norm in summer and 1.7 °C below the established norm in winter. The humidity was below the norm by 9.7% and 1.6% in summer and autumn, respectively, and above the norm by 9.6 % and 6.6 % in winter and spring, respectively. The airflow was 0.1 m/s lower than the norm in summer, winter, and spring. The general illumination was 3.8 and 2.6 LUX lower than the norm in winter and spring, respectively. The average morbidity (cumulative incidence of all four diseases) was 63.8% (highest) in the winter, followed by spring (60.0%). Average morbidity was considerably less in summer and autumn at 46.7% and 37.1%, respectively. Study results indicate that minor deviations in microclimate parameters from the norms, particularly in winter and spring, can considerably impact the disease incidence on dairy farms in Kazakhstan. The farm management should strive to maintain microclimate conditions on the farm as close to the norm as possible during different seasons to avoid losses from livestock morbidity.

Keywords: foot diseases, loose housing, reproductive diseases

1. Introduction

Due to exposure to suboptimal microclimatic conditions, the stress in dairy cows can lead to poor health and diseases such as ketosis, mastitis, retained placenta, foot disease, and reproductive failure (Sordillo 2016; Dahl 2020). Ketosis is a body condition characterized by a negative energy balance and excessive ketone bodies in the blood of cows. Ketosis typically occurs in dairy cows during the early lactation period and less often in late gestation. The symptoms of ketosis include loss of appetite, reduced milk production, a dull coat, and sometimes nervous system dysfunction. The incidence of ketosis can be as high as 40%-80% in a lactating herd (Andersonn 1988; Duffield 2000). Mastitis is a persistent inflammation of the breast tissue due to infection or trauma. Chronic inflammation causes an influx of white blood cells in the breast tissue, leading to excessive somatic cell counts in milk and a decrease in the quality and quantity of milk. Mastitis is one of the most economically damaging diseases in the global dairy industry, with an estimated annual loss of 53 billion dollars (Pal et al 2019). Common reproductive disorders occurring in cattle are infertility, abortions/stillbirths, dystocia, retained placenta, and metritis (Suthar et al 2013; Berge and Vertenten 2014). Globally, diseases of the reproductive system in cows result in the second largest cause of economic loss to dairy farmers. Foot diseases cause lameness in cattle and are the third most economically damaging conditions in the dairy industry (Ozsvari 2017). Affected animals spend more time lying down, predisposing them to sores and mastitis. These animals also eat less and are more likely to develop secondary disorders due to poor nutrition.

Temperature, humidity, air velocity, and light are four important microclimatic parameters that affect cattle health. Holstein-Friesian cows can generally tolerate a temperature between 0-25 °C without any significant effect on milk production (Angrecka et al 2015). Temperatures outside this range result in stress that can increase the risk for diseases, mainly due to the negative effect of stress hormones on physiological and immune system functions (Burdick et al 2011; Gebermariam 2019; Herbut et al 2019; Bova et al 2014). Humidity acts in conjunction with temperature in determining the amount of heat lost from an animal's body and thus can modulate the effect of temperature. The air velocity inside the farm also influences the amount of heat lost from cows' body by affecting convection cooling of the body surface. Dairy cows require fresh and clean air to achieve their production potential. High moisture levels, toxic gases from manure, pathogens, and excessive dust particles present in areas with a low air exchange rate can increase the incidence of diseases. Light has important effects on physiology, milk productivity, and cattle health. Various studies have reported the effect of light intensity and

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photoperiodicity on animals' immune systems (Achtung et al 2004). Light also affects cattle's feeding behavior and thus metabolism (Bodurov 1979; Penev et al 2014).

This study aimed to evaluate the effect of microclimatic conditions on the prevalence of diseases in dairy cows in three dairy farms of North Kazakhstan in four consecutive seasons.

2. Materials and Methods

2.1. Farm locations and measurement of microclimatic conditions

The study was conducted during four consecutive seasons in 2019 (summer and autumn) and 2020 (winter and spring) in three commercial dairy farms located in the northern region of Kazakhstan: Familyfarm in Akmola district (Farm 1), Zelyonie Luga in The North Kazakhstan district (Farm 2), and Konvisher Farm in Pavlodar district (Farm 3). The animals were kept in loose hosing conditions and maintained in individual lying boxes while floors were padded with 5 kg of straw daily. The manure was mechanically removed twice daily from manure corridors. Cows were allowed to feed without restriction on a total mixed ration except during milking. Animal care and handling procedures followed the guidelines of the Ethics Local Committee on the Use of Animals in Experiments.

The following microclimate parameters were measured in dairy complexes: temperature, relative humidity, airflow velocity, and light intensity. The temperature and humidity were measured using a HT-3000 thermo-hygrometer (Delmhorst, New Jersey, USA), the airflow velocity was measured using a METEOSCOPE-M device (NTM-Zashchita LLC, Russia, GOST 30494-96), and the light intensity was measured using a TKA-Lux device (NTP TKA, Russian Federation, GOST 8.332). The sensors were placed at the height of 1 m above the ground in three different areas on the farm: the milking parlor, the barn, and the maternity room. Measurements were recorded daily on all three farms at 11:00 a.m. The microclimatic parameters were recorded at all three areas on the farm, and the parameter values were averaged to obtain a single value of a particular parameter for that day. Parameter values were recorded on all days of each season and averaged to obtain a single value for that specific season. Finally, the average values of a parameter recorded at all three farms were averaged to obtain a single overall value for each parameter.

2.2. Determination of disease prevalence

The cows with mastitis, foot disease, reproductive system diseases, and ketosis were identified based on clinical signs as follows:

Mastitis: The udders and teats of lactating cows were examined before milking and sample collection. Clinical examination was performed according to Radostitis et al (2007). Each cow's udder was inspected to check the symmetry of the quarters, followed by thorough palpitation to detect possible fibrosis, inflammatory swelling, atrophy of the udder tissue, and swelling of the supramammary lymph nodes. The viscosity and appearance of milk from each mammary quarter were examined for the presence of clots, flakes, and watery secretions (Biffa et al 2005).

Foot disease: animals with abnormal postures or experiencing difficulty in walking were visually located.

Reproductive system diseases: The cows that experienced abortion, dystocia, still birth, anestrus, retained placenta, uterine discharges and uterine and vaginal prolapse were categorized as having reproductive system diseases.

Ketosis: The milk of each cow was tested at an interval of 10 days using the Self–Stik MK milk ketone testing kit (Chungdo Pharm Co. Ltd., Gangwon-do, China). The cows with a milk ketone reading of $\geq$100 µmol/L were further tested by drawing blood from the tail vein and determining blood β-hydroxybutyric acid concentrations using the bovine ketone test strips and CentriVet meter (Acon, San Diego, USA). The cows with a blood BHBA concentration $\geq$ 1400 µmol/L were considered to be suffering from ketosis.

3. Results

3.1. Microclimatic conditions on three farms in different seasons

Table 1 presents the average microclimatic parameters recorded on three farms in four consecutive seasons. On Farm 1, which is located in the Akmolinsk region, average temperatures (°C) were 13.1 in summer, 10.5 in autumn, 6.4 in winter, and 7.5 in spring; the average indoor humidity (%) was 40.9 in summer, 47.5 in autumn, 73.6 in winter and 74.5 in spring; the average airflow rate (m/s) was 0.4 in summer, 1.2 in autumn, and 0.3 in winter and spring; and the average illumination index (LUX) was 75.3 in summer, 80 in autumn, 64 in winter and 66 in spring.

On Farm 2, which is located in the northern region of Kazakhstan, average temperatures (°C) were 13.0 in summer, 7.6 in autumn, 6.1 in winter and 6.9 in spring; the average indoor humidity (%) was 36.4 in summer, 48.6 in autumn, 88.5 in winter and 79.1 in spring; the average airflow rate (m/s) was 0.5 in summer, 0.9 in autumn, 0.5 in winter and 0.7 in spring; and the average illumination index (LUX) was 80.0 in summer, 75.3 in autumn, 63 in winter and 69.6 in spring.

On Farm 3, which is located in the Pavlodar region, average temperatures (°C) were 13.7 in summer, 7.1 in autumn, 6.4 in winter, and 7.5 in spring; the average indoor humidity (%) was 43.6 in summer, 49.2 in autumn, 76.7 in winter and 76.3 in spring; the average airflow rate (m/s) was 0.5 in summer, 0.9 in autumn, and 0.4 in winter and spring; and average illumination index (LUX) was 86.6 in summer, 87.3 in autumn, 96.6 in winter and 81.6 in spring.

Table 1 Average microclimatic parameters recorded in three farms in different seasons.

Seasons	Farm 1				Farm 2				Farm 3				Average for 3 farms, °C
	MIA[a]	HOA[b]	MAA[c]	Average	MIA	HOA	MAA	Average	MIA	HOA	MAA	Average	
	Temperature, °C				Temperature, °C				Temperature, °C				
Summer	12.4	13.2	13.9	13.1	12.0	13.7	13.5	13.0	13.5	14.5	13.2	13.7	13.2
Autumn	11.5	10.5	9.5	10.5	8.7	7.3	7.0	7.6	8.6	6.1	6.7	7.1	8.4
Winter	7.0	5.8	6.4	6.4	6.3	5.2	6.9	6.1	6.2	5.8	7.4	6.4	6.3
Spring	6.5	7.6	8.5	7.5	7.9	6.1	6.8	6.9	6.3	8.0	8.2	7.5	7.3
Norm	8-12				8-12				8-12				
	Humidity, %			Average	Humidity, %			Average	Humidity, %			Average	
Summer	45.2	35.1	42.6	40.9	36.3	32.6	40.4	36.4	46.5	39.1	45.3	43.6	40.3
Autumn	45.5	47.2	50.0	47.5	46.9	50.0	49.1	48.6	49.3	50.1	48.4	49.2	48.4
Winter	70.0	74.4	76.4	73.6	85.4	88.1	92.0	88.5	71.0	82.0	77.2	76.7	79.6
Spring	71.0	75.0	77.6	74.5	76.1	85.0	76.2	79.1	78.0	70.6	80.5	76.3	76.6
Norm	50-70%				50-70%				50-70%				
	Air Velocity, m/s			Average	Air Velocity, m/s			Average	Air Velocity, m/s			Average	
Summer	0.5	0.8	0.4	0.4	0.4	0.5	0.7	0.5	0.6	0.6	0.3	0.5	0.4
Autumn	1.0	1.4	1.2	1.2	0.6	1.0	1.3	0.9	0.9	1.1	0.8	0.9	1.0
Winter	0.4	0.5	0.1	0.3	0.6	0.4	0.5	0.5	0.2	0.3	0.9	0.4	0.4
Spring	0.6	0.3	0.2	0.3	0.7	0.5	0.9	0.7	0.1	0.5	0.6	0.4	0.4
Norm	0.5-1				0.5-1				0.5-1				
	Illumination, Lux			Average	Illumination, Lux			Average	Illumination, Lux			Average	
Summer	70	75	81	75.3	75	82	83	80	85	92	93	86.6	80.6
Autumn	74	81	85	80	70	79	77	75.3	83	89	90	87.3	80.8
Winter	65	60	67	64	62	60	67	63	82	83	95	86.6	71.2
Spring	66	65	67	66	64	71	74	69.6	75	80	90	81.6	72.4
Norm	75-100				75-100				75-100				

[a]MIA: Milking area. [b]HOA: Housing area. [c]MAA: Maternity area

The deviations of the average microclimatic parameters on these three farms from the zootechnical norms were calculated. The average temperature was 1.2 °C above the norm in summer and 1.7 °C below the norm in winter. The average humidity was below the norm by 9.7% and 1.6% in winter and autumn, respectively, and above the norm by 9.6% and 6.6% in summer and spring, respectively. The airflow was 0.1 m/s lower than the norm in summer, winter, and spring. In winter and spring, the general illumination was 3.8 and 2.6 LUX lower than the norm.

3.2. Disease incidence in different seasons

Data on the number of sick animals on three farms in different seasons and the annual incidence of four major diseases are presented in Table 2. The incidence of all diseases increased significantly in the winter and spring seasons. Data for average microclimatic conditions across the three farms, deviations from the norm, and average morbidity across the three farms are presented in Table 3. In summer, the average temperature was slightly above the norm by 1.2 °C, average humidity was below the norm by 9.7%, and the airflow speed was within the norms. In autumn, the average temperature was within norms, the average humidity was below the norm by 1.6%, and the airflow speed was within norms. In winter and spring, the average temperature was below the norm by 1.7 and 0.7 °C, and the average humidity was above the norm by 9.6% and 6.6%, respectively. The airflow was 0.1 m/s less than the norm, while illumination was within norms in winter and spring. The 63.8% average morbidity was highest in winter, followed by 60.0% morbidity in spring. The average morbidity was considerably less in the summer and autumn seasons at 38.5% and 34.3%, respectively.

4. Discussion

The highest morbidity in dairy cattle was observed in winter at 63.8%, followed by that in spring season at 60.0%. The morbidity in summer and autumn was considerably lower at 45.6% and 37.1%, respectively. This difference in mortality may be related to microclimatic conditions on farms in different seasons. The average air temperature in winter is slightly below the norm by 1.7±0.9 °C, which may affect the health of some animals by causing low-temperature stress. In winter, the relative humidity of 79.6% was also higher than the norm by 9.6%, which may have deleterious effects on the health of the animals. High humidity is conducive to the growth of pathogens (Zucker et al 2000; Xiong et al 2017) in the environment, leading to higher incidences of infectious diseases such as mastitis, foot infections, and infectious reproductive diseases. Low temperatures and high humidity can also affect cattle adversely by increasing the heat conductance through their coat and increasing the effect of cold temperatures. Atmospheric water molecules associate with coat hairs and increase heat conductance at higher humidity levels. Thus, cattle lose greater heat and feel a greater effect of cold weather.

Table 2 Indicators of animal morbidity by season in three dairy farms of the northern region of Kazakhstan.

Farm 1					
Seasons	Disease incidence				Cumulative incidence of diseases in a season – Absolute value (%)
	Ketosis	Foot ailment	Reproductive diseases	Mastitis	
Summer	4	6	9	8	27 (38.5%)
Autumn	3	5	8	8	24 (34.3%)
Winter	11	12	14	14	39 (55.7%)
Spring	10	11	13	12	36 (51.4%)
Annual Incidence	38 (54.2%)	34 (48.6%)	45 (64.3%)	39 (55.7%)	
Farm 2					
Seasons	Disease Incidence				Cumulative Incidence of Diseases in a season – Absolute Value (%)
	Ketosis	Foot ailment	Reproductive diseases	Mastitis	
Summer	7	7	9	9	32 (45.7%)
Autumn	5	6	9	9	29 (41.4%)
Winter	13	13	10	10	46 (65.7%)
Spring	11	11	10	10	42 (60.0%)
Annual Incidence	36 (51.4%)	37 (52.8%)	38 (54.2%)	38 (54.2%)	
Farm 3					
Seasons	Disease Incidence				Cumulative Incidence of Diseases in a season – Absolute value (%)
	Ketosis	Foot ailment	Reproductive diseases	Mastitis	
Summer	9	9	11	10	39 (55.7%)
Autumn	5	5	7	8	25 (35.7%)
Winter	10	11	14	14	49 (70.0%)
Spring	13	13	11	11	48 (68.6%)
Annual Incidence	37 (52.8%)	38 (54.2%)	43 (61.4%)	43 (61.4%)	

The air velocity on farms is reduced in winter due to the covering of open areas to protect animals from cold temperatures. This reduced ventilation leads to a greater buildup of many undesirable and poisonous gases and odors in the farm area. Cattle manure produces many harmful gases, such as ammonia and hydrogen disulfide. It releases unpleasant odors that have harmful effects on cattle health by irritating mucous membranes, increasing stress, and depressing the immune system. A depressed immune system increases the susceptibility of cattle to infectious diseases (Osorio et al 2009). High ammonia concentrations cause inflammatory processes in the mammary glands, respiratory system, and other organs. When absorbed into the blood, ammonia decreases blood glucose, hemoglobin, and red blood cells and can cause damage to the central nervous system and even animal death. Long-term exposure of greater than 1% CO_2 in the air can cause chronic intoxication, lower productivity, and decreased disease resistance (EFSA report 2009).

A slight reduction in light intensity below the norm recorded in winter and spring was noted. Unlike air temperature, humidity, and wind speed, small changes in illumination are not expected to have a major effect on animal welfare and were not evaluated further.

Similar deviations from the norms (but less than that in winter) in temperature, humidity, and air velocity were observed in the spring season, which may explain a high but slightly less incidence of diseases in spring than winter.

Our results show that the cumulative effect of minor deviations from the norms of temperature, humidity, and air velocity can significantly increase disease incidence in farm cattle. The high-yield cow breeds, which deliver 8000-10000 kg milk per year, are highly susceptible to unfavorable environmental conditions. Even slight deviations from the norms can deteriorate animal health and productivity (Walsh et al 2007; Litwińczuk et al 2015). Thus, the importance of maintaining a proper microclimate in a dairy farm cannot be overstated. It may be economically beneficial to use farm microclimate monitoring and maintenance systems to tightly maintain farm microclimate parameters, provided that their use is economically feasible in Kazakhstan. The development of affordable indigenous farm microclimate monitoring and maintenance systems in Kazakhstan can widespread acceptance and milk productivity improvements.

Previous studies have reported the effect of seasons on disease prevalence in cattle. Bangar et al (2015) found an increased incidence of reproductive disorders in cattle in summer and gastric disorders in winter. This study was performed in India, where a significant part of the cattle population consists of local Indian breeds. The sub-tropical climatic conditions of India are very different from Kazakhstan, which explains the different patterns of seasonal disease prevalence. Gröhn and Bruss (1990) reported that the incidence of ruminal acidosis tends to be lowest in summer. In a study on seasonal variations in the prevalence of ten different cattle diseases in Ontario, Canada, a record of 5990 individuals revealed that the overall disease prevalence increased in winter with a marked increase in the prevalence of cystic Graafian follicle, ketosis, and pyometra. The authors did not describe the microclimatic conditions on the farm; however, temperatures in Ontario fall below the freezing point in winter as in Kazakhstan, and similar farm microclimate conditions are expected in Ontario and northern Kazakhstan (Erb and Martin 1978). The findings of this study are consistent with our studies. In yet another study, the risk of ketosis and tramped teat increased during winter in the Swedish Red and White breed of cattle (Bendixen et al 1986).

Table 3 Average indicators of microclimate parameters, percentages of sick and clinically healthy cows by season in three dairy complexes of the northern region of Kazakhstan.

Season	Microclimate parameters (average of three farms)								Health status	
	Temperature (°C)	Deviation from norm (°C)	Humidity (%)	Deviation from the norm (%)	Air velocity (m/s)	Deviation from the norm (m/s)	Illuminati-on (Lux)	Deviation from the norm, Lux	Average morbidity Absolute value (%)	Healthy Absolute value (%)
Summer	13.2	Above the norm by 1.2	40.3	Below the norm by 9.7	0.4	Below the norm by 0.1	80.6	`	32.7 (46.7%)	37.3 (53.3%)
Autumn	8.4	Within the norm	48.4	Below the norm by 1.6	1.0	Within the norm	80.8	Within the norm	26.0 (37.1%)	44.0 (62.9%)
Winter	6.3	Below the norm by 1.7	79.6	Above the norm by 9.6	0.4	Below the norm by 0.1	71.2	Less than the norm by 3.8	44.7 (63.8%)	25.3 (36.2%)
Spring	7.3	Below the norm by 0.7	76.6	Above the norm by 6.6	0.4		72.4		42.0 (60.0%)	28.0 (40.0%)
Norm	8-12		50-70%		0.5-1		75-100			

5. Conclusions

The incidence of ketosis, mastitis, reproductive diseases, and lameness in the Holstein-Friesian breed of cattle increased in winter and spring in three loose-housing cattle farms located in North Kazakhstan. The cumulative effect of minor deviations in the temperature, humidity, and air velocity negatively affected cattle health and thus farm productivity. Our results indicate that it is important to tightly control microclimatic conditions on loose-housing farms, particularly in winter and spring, to minimize the morbidity of cows and realize the full potential of high-yield breeds of cattle. Further studies with a larger number of dairy cows and longer duration, allowing multiple observations for each season, will help overcome some of the limitations of this study, such as a small sample size of 210 cows and a single observation for each season.

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Conflict of Interest

The authors declare no conflicts of interest.

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