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Stress resistance as a factor in the suitability of cattle for robotic milking

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***Abstract*—The use of industrial technologies in modern enterprises, based on the comprehensive modernization of most production processes, leads to an increase in the impact of a number of negative factors and their quantity. This contributes to the stress in animals. The purpose of this research is to assess the stress resistance of cows of various origins, as a factor affecting the suitability of animals for robotic milking. These studies were conducted on the basis of the "Sovkhoz Chervishevsky" in the Tyumen region. Hematological and clinical-physiological parameters of the studied cattle groups showed that all animals are clinically healthy. Cows with loose housing and robotic milkers were more often stressed – the amount of cortisol and adrenocorticotropic hormones is much higher in the blood of these animals, compared to the other group of animals (stanchion-tied, milking pipelines), on average by 4.19 nmol/l (11.3%) and 5.27 pg/ml (5.8%), respectively. At the same time, the largest percentage of cows with a high type of stress resistance is 50.8% of all cows of the other group. Simmental cattle have higher levels of cortisol and ACTH, compared to Russian Black Pied cattle. The difference in this case was 2.14 nmol/l (5.6%) and 1.18 pg/ml (1.3%), respectively. Russian Black Pied cattle was the leader in the milk yield for a 305 days of lactation period, they were on the loose housing system with robotic milking and made a yield of an average 430.5 (8.1%) (p <0.001). The superiority of Russian Black Pied cattle over the Simmentals was established – by 6.0 kg of milk yield (0.1%). Consequently, the use of a robotic milking system for cattle makes it possible to obtain higher milk yield during the lactation period with a fairly stable indicator of the mass fraction of fat and protein in milk. At the same time, animals of Russian Black Pied cattle turned out to be more stress-resistant in this case as compared with cows of the combined Simmental breed.**

***Keywords*—types of cattle stress resistance, robotic milking, cortisol, prolactin, adrenocorticotropic hormone, milk productivity.**

I. INTRODUCTION

Stress-free cattle housing is the basis for the rational and effective breeding of animals in high-tech dairy complexes, along with the intellectual technology of the new generation [1]. The use of industrial technologies in modern enterprises, based on the comprehensive modernization of most production processes, leads to an increase in the impact of a number of negative factors and their quantity. This contributes to the stress in animals [2, 3, 4].

Animals are forced to constantly adapt to the conditions of their existence, and there is a huge amount of them in modern dairy farms and complexes. Stress adversely affects the health and productive longevity of cattle. Therefore, it is extremely important to identify animals with a high level of stress resistance in order to subsequently obtain the maximum amount of high quality products [5, 6, 7, 8].

The factors of stress include: violation of the microclimate parameters, poor sanitary and hygienic condition of facilities, high flock density, and noisiness. Adverse microclimate conditions contribute to a decrease in the productivity of cows by 15-30%, the morbidity and mortality increase by 15-35%. Violation of the temperature regime leads to an increased feed intake by 20-30%, and daily weight gain decreases by 25-30%. Highly dusty or polluted air and elevated noise levels are also a consequence of technological stress that contribute to the infection of animals and their morbidity [9, 10].

According to the authors, up to 30% of highly productive cows drop out of the herd every year due to mortality, because of the stress state [11].

Nowadays, cattle robotic milking is widely used at many milk producing enterprises. But not all animals were sufficiently adapted to this technology. A separate breed, line, family, and production group react differently to the stress factors, acting in the process of applying intensive technologies [12].

The purpose of this research is to assess the stress resistance of cows of various origins, as a factor affecting the suitability of animals for robotic milking

II. METHODS

Scientific work was conducted on the basis of the breeder flock of "Sovkhoz Chervishevsky", in Tyumen region.

In order to carry out the scientific research, first lactation heifers are formed into 3 groups, depending on the origin and on the managing and milking technology (124 cows in each group). The 1st group: Russian Black Pied breed, loose housing, robotic milking by Lely robots. The 2nd group: Simmental breed, loose housing, robotic milking by Lely robots. The 3rd group: Russian Black Pied breed, stanchion-

tied, milking in the milking pipelines with the DA-2M "Maiga" machines.

Feeding of the estimated groups was carried out according to the feeding program, adopted at the enterprise, which was made in accordance with the age, lactation period, level of productivity, body weight and physiological state of the cows.

To monitor the physiological parameters of animals that characterize their health, the biochemical composition of the blood of cows on the 2nd-3rd months of lactation (5 animals in each group) was analyzed in the Tyumen regional veterinary laboratory. The amount of erythrocytes and leukocytes (Goryaev chamber) and hemoglobin level (Sahli method) were estimated using standard methods. Serum total protein (refractometer "RL"), calcium content (trilonometry method), inorganic phosphorus (Briggs method, modified by Ivanovsky) were determined. The obtained results were compared with the physiological standards (V.F. Voskoboinik).

To assess the clinical and physiological indicators of cows at 45-50 days of lactation (5 animals in each group), we measured: body temperature – with a veterinary thermometer in the rectum; pulse rate per minute – by imposing a finger on the femoral artery; respiratory rate – according to the movement of the chest according to the number of breaths per minute.

We distributing the studied animals according to the types of stress resistance, the level of hormones in the blood of the studied animals was determined (124 heads in each group) during the period yield increasing, using special tests Steroid ELISA-Cortisol-01 ("Alkor Bio", Russia) and Adrenaline ELISA (Labor Diagnostika Nord GmbH & Co. KG, Nordhorn).

The indicators characterizing the milk productivity were determined in accordance with the "Rules for assessing the milk productivity of cows of milk and meat breeds of SNPplem R23-97".

III. Research results

Hemoglobin is the main structural and chemical component of the red blood cells. An increase in the hemoglobin content occurs mainly during muscular fatigue and during pathological conditions, which are accompanied by thickening of the blood of cows. The decrease in this indicator is observed much more often and means the presence of infectious and invasive diseases in the animal, exhaustion, any deviations, poisoning and anemia.

In our research, the number of erythrocytes and hemoglobin is higher in the 3rd group than in the 1st group, by 0.08*1012/l (1.5%) and 0.19 g/l (0.2%),; and than in the second – by 0.02*1012/l (0.4%) and 0.03 g/l (0.02%), respectively (Tab. 1).

At the same time, the color indicator in the 1st group of cows is higher than in the 2nd and the 3rd groups by 0.01 (1.4%).

The number of erythrocytes increases with muscular tension due to thickening of the blood due to excessive sweating. Most likely, this arose as a result of redox processes in the body of the 3rd group of cows.

TABLE I. Hematological parameters of cows of different origin, depending on the technology of milk production, $\overline{X} \pm S_{\overline{X}}$

Index	Cattle groups			Standards (V.F. Voskoboinik, 1988)
	1st, Russian Black Pied cattle	*2nd, Simmental cattle*	*3rd, Russian Black Pied cattle*	
Erythrocytes, *10^{12}/l	5.34±0.04	5.40±0.01	5.42±0.01	5.00-7.50
Hemoglobin, g/l	126.74±0.10	126.90±0.07	126.93±0.05	99.00-129.00
Color index	0.71±0.01	0.70±0.00	0.70±0.00	0.70-1.00
Leukocytes, *10^9/l	8.20±0.45	8.50±0.37	8.74±0.25	4.50-12.00
Alkaline reserve, mg %	534.80±5.53	538.00±10.79	544.00±14.09	450.00-550.00
Total protein, g/%	8.38±0.21	8.39±0.14	8.48±0.14	7.20-8.60
Calcium, mmol/l	2.57±0.04	2.61±0.01	2.65±0.01	2.50-3.13
Inorganic phosphorus, mmol/l	1.75±0.01	1.76±0.01	1.78±0.02	1.45-1.94
Potassium, mmol/l	4.42±0.02	4.40±0.01	4.36±0.02	4.10-4.86
Sodium, mmol/l	144.62±0.01	144.58±0.01	144.55±0.04	139.00-148.00

The number of leukocytes in heifers of the 3rd group is higher by 0.54 *109/l (6.2%) in comparison with the 1st group – by 0.24 * 109/l (2.7 %). In our opinion, this quite clearly shows the intensity of metabolism and lactogenesis in the animals of the estimated groups.

An active blood reaction is provided by alkaline buffer. It was established that this indicator in heifers of the 3rd group is higher in comparison with the 2nd and 1st group sby 6.0 mg% (1.1%) and 9.2 mg% (1.7%), respectively.

An increase in the total protein in cows is observed during the period of lactation increasing. But at the same

time, the total protein content in high-fat animals in the first months of lactation undergoes a slight decrease due to more intensive metabolic processes that are associated with milk synthesis. The amount of total protein is quite high. At the same time, in the first two groups this indicator is slightly lower than in the 3rd: in the 2nd group by 0.09 g/% (1.1%), in the 1st group - by 0.1 g/% (1.2 %).

Disorders of metabolism of calcium, which is part of all cells of the body and is involved in many physiological processes, lead to a significant decrease in productivity, reduction of immune resistance of the body and diseases. During periods of growth and development of cattle, pregnancy and at high milking yield – calcium is necessary in a larger amount. The amount of calcium in the blood of animals of the 3rd group is higher than the 1st and 2nd groups by 0.08 mmol/l (3.0%) and 0.04 mmol/l (1.5%), respectively.

The value of such an indicator as the content of inorganic phosphorus in the blood serum of cows should be judged on the availability of phosphorus compounds to the animal organism. Phosphorus, in turn, takes an active part in the creation of buffer systems, acts as an activator of carbohydrates and amino acids.

The content of phosphorus in the 3rd group is higher by 0.02 mmol/l (1.1%) and 0.03 mmol/l (1.7%) than in the 2nd and 1st groups, respectively. It can be assumed that the low amount of phosphorus is due to its more intensive use for the milk synthesis.

The content of individual blood ions, such as potassium and sodium, is higher in the 1st group than in the 3rd group by 0.06 mmol/l (1.4%) and 0.07 mmol/l (0.05%), respectively, and than in the 2nd group – by 0.02 mmol/l (0.5%) and 0.04 mmol/l (0.03%), respectively.

Among other things, it is quite objective and rational to analyze many biological features, as well as the physiological state of the cattle, according to some clinical and physiological indicators (Tab. 2). When analyzing the data, we found out that all the evaluated clinical and physiological parameters of the animals were within the normal range.

The body temperature of the estimated groups ranged from 38.24 to 38.25 °C. At the same time, there was an increase in this indicator in the heifers of the 3rd group by an average of 0.09 °C, in comparison to the other groups.

Pulse rate, reflecting the heart and vascular system state, is more rapid in heifers of the 1st group on average of 0.72 beats per minute.

Respiratory rate characterizes the metabolic rate in animals. The cows of the 1st group had on average 0.56 respiratory movements per minute more than the cows of the 2nd and 3rd groups.

Stress tolerance of animals is characterized by a number of hormones. Stress is the activation of the sympathetic nervous system or ligament “hypothalamus - pituitary - adrenal glands” due to the influence of some environmental factor.

Among the hormones involved in the regulation of lactation, prolactin takes the leading place, which stimulates the function of the mammary glands, enhances the synthesis of milk precursors. Prolactin activates tissue respiration, metabolic processes and the growth of mammary epithelial cells.

In our studies, it was established (Tab. 3) that the level of prolactin in the blood of cows of the 1st group is higher compared to the 2nd and 3rd groups by 4.40 and 17.40 ng/ml (2.7 and 10.7%), respectively ($p < 0.001$).

It was found that the content of adrenocorticotropic hormone (ACTH) in the cows of the studied groups differed. For example, in the groups of Russian Black Pied and Simmental cattle, which were on the loose housing with robotic milkers (the 1st and 2nd groups), the level of ACTH is on average 5.27 pg/ml (5.8%) higher, compared to the 3rd group (stanchion-tied, milking pipelines) ($p < 0.001$). Such a significant increase in the concentration of the studied hormone in the blood of animals can be explained by the fact that animals of the 1st and 2nd groups were exposed to the production stress factor in the form of an intensive producing milk technology – the robotic milking. Due to the action of any stress, the activity of the pituitary gland is triggered and adrenocorticotropic hormone is released.

It should be noted that the amount of released ACTH in animals of the Russian Black Pied breed is 1.18 pg/ml (1.3%) less, compared to Simmental breed.

TABLE II. CLINICAL AND PHYSIOLOGICAL INDICATORS OF HEIFERS OF DIFFERENT ORIGIN, DEPENDING ON THE TECHNOLOGY OF MILK PRODUCTION, $\overline{X} \pm S_{\overline{X}}$

Index	**Cattle groups**			**Standards (A.P. Kalashnikov, 2003)**
	1st, Russian Black Pied cattle	***2nd, Simmental cattle***	***3rd, Russian Black Pied cattle***	
Body temperature, °C	38.28±0.03	38.24±0.04	38.35±0.03	37.5-39.5
Pulse rate per minute	75.64±0.10***	75.24±0.08	74.60±0.09	65-75
Respiratory movements per minute	28.44±0.14***	28.34±0.05	27.42±0.06	15-30

TABLE III. HE CONCENTRATION OF HORMONES IN THE BLOOD OF HEIFERS OF DIFFERENT ORIGIN, DEPENDING ON THE TECHNOLOGY OF MILK PRODUCTION, $\overline{X} \pm S_{\overline{X}}$

Index	Cattle group		
	1st, Russian Black Pied cattle	*2nd, Simmental cattle*	*3rd, Russian Black Pied cattle*
Prolactin, ng/ml	163.3±2.0***	158.9±1.10***	145.9±0.96
Adrenocorticotropic hormone, pg/ml	89.80±0.24	90.98±1.12***	85.12±0.68
Cortisol, nmol/l	35.92±0.09***	38.06±0.18***	32.80±0.15

The steroid hormone cortisol is one of the hormones most responsible for the stress state. It is produced by the adrenal glands in extreme situations. The hormone cortisol affects the metabolism of carbohydrates, proteins and fats, causing an increase in blood glucose levels, stimulating the formation of carbohydrates from amino acids, reducing protein synthesis and increasing the decay of fats.

In our research, it was found that the content of cortisol is 32.80 nmol/l in the heifers of the 3rd group, which is on average 4.19 nmol/l (11.3%) (p <0,001) less, compared to the first two groups.

It should also be noted that Simmental cattle have a much higher level of cortisol, compared to the Russian Black Pied cattle, when using a similar technology for producing milk (loose housing, robotic milking). The difference in this case was 2.14 nmol/l (5.6%) (p <0.001).

The distribution of cows of different origin, according to the types of stress resistance depending on time of the normalization of homeostasis, established (Fig. 1) that in the 1st group of Russian Black Pied cattle (loose housing, robotic milker) 25.8% of cows had high resistance to stress; in the 2nd group with Simmental cattle (loose housing, robotic milker) – 13.7%. At the same time, in the 3rd group (stanchion-tied, milking pipelines), cows with a high type of stress tolerance turned out to be more than a half – 50.8%.

Heifers with an unstable type of stress resistance in the 1st and 2nd groups were about the same number - ranging from 52.4% to 59.9% of cows. At the same time, animals with an unstable type of stress resistance in the 3rd group were only 37.9%.

Animals with low stress tolerance are mostly in the 2nd group – 33.9%, which is 18.6 and 22.6%, respectively, more than in the 1st and 3rd groups of animals.

When taking into account the indicators, characterizing the milk productivity of animals of different groups, it was established (Table 4) that in the first lactation in cows of the 1st group for 100, 305 days and for the entire lactation period, the amount of produced milk is greater than in animals of the 2nd and 3rd groups, on average, by 183.0 (8.8%) (p <0.001), 430.5 (8.1%) (p <0.001) and 564.0 kg (8.4%) (p <0 , 05), respectively.

It should be noted that the animals of the Russian Black Pied breed (the 1st group) were superior over the Simmental cows (the 2nd group) by the same indicators: for the first 100 days – by 30.0 kg (1.4%), for 305 days – by 6.0 kg (0.1%), for the entire lactation period – by 499.0 kg (7.5%).

In the third group of heifers, the lactation period was 495.0 days. This is an average 110.0 days (22.2%) (p <0.001) longer, than in the 1st and 2nd groups.

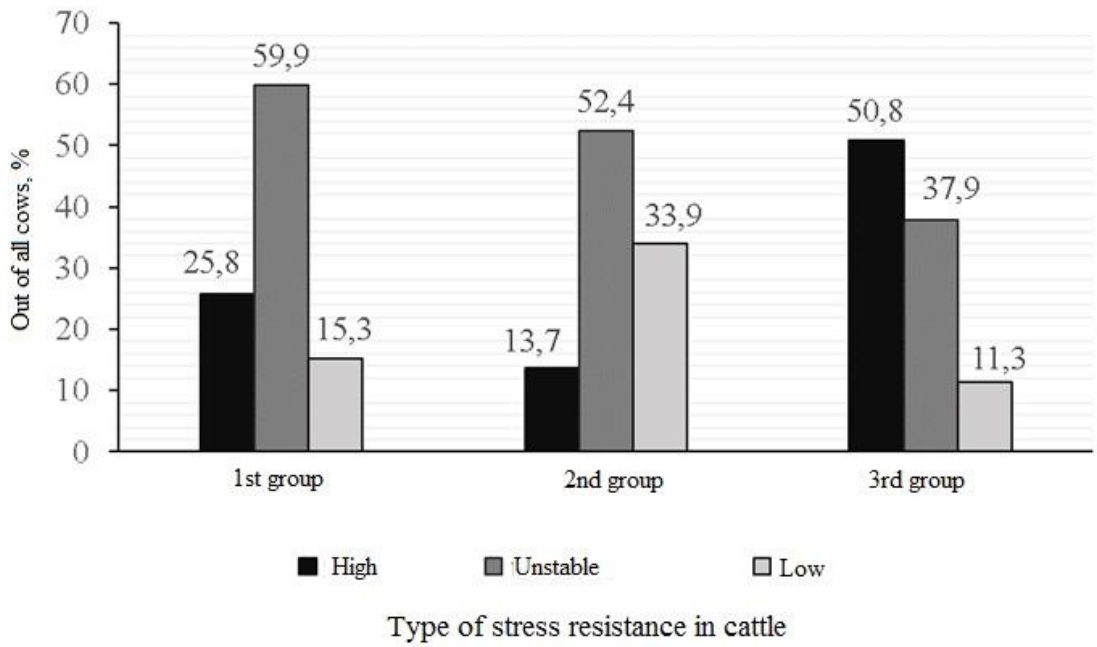

Fig. 1. Distribution of cows of different origin by types of stress resistance, %

TABLE IV. MILK YIELD AND FIRST LACTATION CHARACTERISTICS OF COWS OF DIFFERENT ORIGIN, DEPENDING ON THE TECHNOLOGY OF MILK PRODUCTION

Index	Cattle group					
	1st, Russian Black Pied cattle		*2nd, Simmental cattle*		*3rd, Russian Black Pied cattle*	
	$\overline{X} \pm S_{\overline{X}}$	Cv, %	$\overline{X} \pm S_{\overline{X}}$	Cv, %	$\overline{X} \pm S_{\overline{X}}$	Cv, %
Milk yield for the first 100 days of lactation, kg	2078.0 ±45.3***	21.3	2048.0 ±45.3***	26.4	1742.0 ±44.2	28.5
Milk yield for the 305 days of lactation, kg	5294.0 ±98.8***	20.7	5288.0 ±94.4***	21.3	4439.0 ±111.1	28.1
Milk yield for the whole lactation period, kg	6683.0 ±222.4*	37.7	6184.0 ±124.2	23.9	6054.0 ±192.7	35.7
Lactation period in days	397.0 ±12.4	35.3	373.0 ±7.6	24.4	495.0 ±22.2***	50.3
Fat mass fraction, %	3.60±0.02	5.8	3.58±0.01	3.7	3.67±0.04*	12.9
Milk fat, kg	193.2 ±3.32***	19.5	188.8 ±3.24	20.4	162.3 ±3.90	27.0
Protein mass fraction, %	3.03±0.01	3.7	3.02±0.01	4.8	2.96±0.04	13.2
Milk protein, kg	163.6 ±3.07***	21.2	159.6 ±2.86***	21.4	131.0 ±3.1	26.9

In addition, it was found that the indicator of the mass fraction of fat in the milk of animals of the 3rd group is higher than in the 1st and 2nd groups on average by 0.08% ($p < 0.05$). At the same time, the mass fraction of protein in milk of the heifers of the 3rd group is slightly lower, compared to the 1st and 2nd groups on average by 0.07%, with an insignificant difference in the results of analyzes.

The content of milk fat and protein is higher in the 1st group ($p < 0.001$) than in the 2nd and 3rd groups on average by 17.7 (9.2%) and 18.3 kg (11.2%), respectively.

In addition, when comparing the quality characteristics of the milk productivity of cows of different genotypes, the superiority of the Russian Black Pied breed over the Simmental breed was established by mass fraction of fat in milk by 0.02% and protein content – by 0.01%.

IV. CONCLUSION

Hematological and clinical-physiological indicators of the studied groups of cattle showed that all animals are clinically healthy, which allowed us to carry out a further analysis of the hormonal background and assess the degree of stress resistance of cows. It was found that animals of the 1st and 2nd groups (loose housing, robotic milking) were more often under stress, since the amount of adrenocorticotropic hormone and cortisol in the blood of these animals is much higher, compared to the animals of the 3rd group (stanchion-tied, milking pipelines) on average at 5.27 pg/ml (5.8%) and 4.19 nmol/l (11.3%), respectively ($p < 0.001$). At the same time, the largest percentage of cows with a high type of stress resistance is 50.8% of all cows of the 3rd group. It can be assumed that robotic milking acts as a stress factor in the given herd. It is also important that the Simmental cows have a much higher level of cortisol and ACTH compared to Russian Black Pied cows, with the same technology for milk production (loose housing, robotic milking). The difference in this case was 2.14 nmol/l (5.6%) ($p < 0.001$) and 1.18 pg/ml (1.3%), respectively. Cows of the Simmental breed are less stress resistant when using intensive milk production technologies.

At the same time, for 100 days, 305 days and for the entire 1st lactation period, the amount of produced milk exceeded in heifers of the 1st group, compared to heifers of the 2nd and 3rd groups on average by 183.0 (8.8%) ($p < 0.001$), 430.5 (8.1%) ($p < 0.001$) and 564.0 kg (8.4%) ($p < 0.05$). Animals of the Russian Black Pied breed (the 1st group) were superior to Simmental cows (the 2nd group) by the same indicators: for the first 100 days – by 30.0 kg (1.4%), for 305 days – by 6.0 kg (0, 1%), for the entire lactation – by 499.0 kg (7.5%).

Consequently, the use of a robotic milking system makes it possible to obtain higher milk yield during the lactation period with a fairly stable indicator of the mass fraction of fat and protein in milk. At the same time, animals of the Russian Black Pied breed in this case turned out to be more stress resistant, in comparison to cows of the combined Simmental breed.

The obtained data will allow agricultural producers to competently plan the production process, conducting a rational selection of animals for efficient production.

REFERENCES

[1] N. Safiullin, and N. Kanalina, “Stress resistance and milk productivity of cows,” Dairy and Beef Cattle Breeding, №4, pp. 28-30, 2013

[2] S.A. Lamonov, V.V. Tkachenko, and M.S. Eremin, “Stress resistance of cows is an important technological feature in dairy cattle breeding,” Bulletin of Michurinsky State Agrarian University, №1, pp. 41-44, 2015

[3] V.V. Chernyakova, and L.A. Zelenskaya, “The effect of stress on the dairy productivity of cattle,” In the collection: Problems in animal husbandry Proceedings of the international scientific-practical conference, pp. 97-102, 2018.

[4] A.P. Kurdeko, and M.V. Bogomoltseva, “Stress in animals under conditions of intensification and modernization of animal husbandry,”

Scientific notes of educational institutions Vitebsk Order of Honor State Academy of Veterinary Medicine, vol. 53, № 2, pp. 84-88, 2017.

[5] G.I. Belkov, and V.A. Panin, "Stress resistance as a factor in the bioresource potential of Simmental and Holstein × Simmental cows," Livestock and feed production, vol. 101, №1, pp. 75-83, 2018.

[6] T.A. Mayorova, "The relationship of stress tolerance and indicators of resistance of cattle," In the collection: Modern problems of veterinary practice in the agro-industrial complex, pp. 127-129, 2016.

[7] N.M. Kosyachenko, A.V. Konovalov, A.V. Ilyina, and D.V. Kononov, "Using stress tolerance and behavioral functions of cattle with modern technologies of milk production," Monograph: Yaroslavl, p. 118, 2013.

[8] S.M. Mikhailov, "The value of cortisol in the stress response of the body," In the collection: Breakthrough scientific research as an engine of science, pp. 75-78, 2018.

[9] V.Yu. Sidorov, "Ecological and technological stress in cattle: how to identify and how to fight," Niva Zauralye, № 9 (120), pp. 14-18, 2014

[10] A.I. Afanasyev, and V.A. Sarychev, "Hormonal status and reproductive function of the Hereford cattle of Canadian and Siberian selection," Veterinary Pathology, №1, pp.47-53, 2016.

[11] E.I. Veremey, V.M. Rukol, V.A. Zhurba, V.A. Komarovsky, and V.A. Khovaylo, "The stress state of the body and its impact on the productivity of cows in dairy complexes," Scientific notes of Vitebsk State Veterinary Academy, vol. 47, №2, pp. 143-145, 2011.

[12] E.A. Skvortsov, O.G. Loretts, and O.A. Bykova, "Efficiency Improvement of Dairy Husbandry with Application of Milking Robotics," International journal of advanced biotechnology and research, vol.9, №1, pp. 579-585, 2018.