DOI https://doi.org/10.30525/978-9934-26-258-6-5

NUTRITIONAL-DEFICIENCY ANEMIA OF COWS

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INTRODUCTION

One of the urgent problems in veterinary hematology is the hypoplastic condition of hematopoietic organs, which is characterized with incomplete, sometimes temporary inhibition of bone marrow function, a decrease in the production of cells of all three lines of hematopoiesis (erythrocytes, leukocytes, platelets). Therefore, when analyzing the causes and pathogenesis of anemia, it is necessary to study the conditions of animals feeding, taking into account the belonging of the territory to a certain biogeochemical zone.

According to the modern data, hypoplastic anemia is a polyetiological disease. The main role in its development is played by exogenous factors, in particular, nutritional deficiencies. It is assumed that the basis of hypoplastic anemia is the pathology of the polypotent hematopoietic stem cells. Therefore, hypoplastic anemia is the disease characterized by suppression of bone marrow hematopoiesis, weakening of the rate of proliferation and delayed maturation of bone marrow elements [1] [2]. Hypoplastic anemia as an independent nosological disease is highlighted in all modern classifications.

1. Prevalence, etiology and state of erythrocytopoiesis and iron metabolism during nutritional-deficiency anemia in cows

Foreign and domestic data related to the study of etiological factors for anemia in cows cannot always be used to evaluate them in our conditions, because there is a difference in breed characteristics, feeding, animals keeping, natural and climatic factors. The problem of mineral nutrition of animals is complicated by the insufficient content of mobile forms of

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[1]. Сукманський О.І., Улизько С.І. Визначення поняття і класифікація анемій. *Вісник Білоцерків. держ. аграр. ун-ту.* 2000. № 13 (2). С. 161–164.

[2] Левченко В.І., Слівінська Л.Г. Поширення аліментарно-дефіцитної анемії у корів у Західних областях України. *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2010. Т. 12, № 3 (1). С. 190–196.

micro-elements in soils and plants. In some geochemical zones, the amount of essential chemical elements is limited, their presence in individual feeds does not meet the needs of the animal body [3] [4]. In particular, Lviv, Volyn, Rivne, Ivano-Frankivsk, and Chernivtsi regions belong to the western biogeochemical zone of Ukraine, which is characterized by a lack of mobile forms of iodine, cobalt, copper, zinc, and manganese.

The lack of the essential micro-elements in the soils and feeds of the western part of Ukraine causes the occurrence of anemia, microelementosis, hypovitaminosis in cows, metabolism disbalance that leads to the development of metabolic disorders and, as a result, reduces the productivity of animals [5].

In order to study the anemia prevalence we have conducted the clinical study of 450 cows and the laboratory analysis of 160 blood samples at the farms of Lviv, Ivano-Frankivsk, Ternopil and Volyn regions (40 in each).

It should be noted that the general condition of the examined cows is satisfactory. Out of 450, only 46 cows (10.2%) were below average body weight, the rest – 404 (89.8%) of average weight. The body temperature of all examined cows was within the normal range. The pulse and respiration rate were increased in 30 and 24.2% of cows, respectively. Most of the cows (55.3%) had a cardiac beat of moderate strength, 17.6% of animals had increased heart tone, 15.3% had a weakened, 8.4% split, and 3.3% had split tones. In the majority (71.6%) of the studied cows, the conjunctiva was pale pink or anemic. 22% of cows were found to have a weak rumen contraction force, a rare, flabby rumination. The enlargement of the percussion borders of the liver was diagnosed in 15.8% of cows, and in some cases its tenderness was established[6].

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[3] Слівінська Л.Г., Щербатий А.Р. Діагностика мікроелементозів кобил у західній біогеохімічній зоні України. *Вет. медицина України*. 2013. № 4 (206). С. 25–28.

[4] Влізло В.В., Сологуб Л.І., Янович В.Г., Антоняк Г.Л., Янович Д.О. Біохімічні основи нормування мінерального живлення великої рогатої худоби. 2. Мікроелементи. *Біологія тварин.* 2006. № 8 (1–2). С. 41–62.

[5] Слівінська, Л.Г., Демидюк С.К., Щербатий А.Р. Синдроматика та стан метаболічних процесів у корів за мікроелементозів. *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2017. Т. 19. № 78. С. 182–186.

[6] Левченко В.І., Слівінська Л.Г. Поширення аліментарно-дефіцитної анемії у корів у Західних областях України. *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2010. Т.12. № 3 (45). С. 190–196.

Despite the deficiency of nutrients, including ME, individual animals can adapt to the micronutrient background, but in a significant part of the herd during the stable period of maintenance, metabolic disorders are manifested, mainly in the form of syndromes and rarely as individual symptoms[7] [8]. Therefore, anemia, anorexia, changes in the cardiac work (tachycardia), hypotonia of the antrum, and hepatomegaly are present in most of the studied cows.

If we follow the definition of anemia, then, according to our data, the disease was established in 84 cows out of 160 studied (52.5%), including a combination of oligochromemia and oligocythemia was detected in 57 cows (35.6%), only oligochromemia – 25 (15.6%) and only oligocythemia – in 2 cows (1.25%) [9].

However, in the literature, anemia is sometimes defined only by a decrease in the amount of hemoglobin per blood volume unit [10] [11]. Even with this definition, anemia was established in 82 cows out of 160 studied (51.3%; Table 1).

Anemia in cows is usually normochromic (84.5%) and normocytic (95.24%), less often hyper- (9.5%) or hypochromic (6%) and macrocytic (4.76%).

Among the 4 regions, anemia was most often diagnosed in Volyn region (100% of cows). In the majority of cows suffering from anemia, the number of both erythrocytes and hemoglobin was reduced (57 cows, 35.6% of the studied or 67.9% of the total number of patients with anemia), oligochromemia only was rarely diagnosed (25 cows, respectively, 15.6 and 29.8%). Macrocytic anemia was detected only in cows of Lviv region, hyperchromic – in Lviv and Ivano-Frankivsk regions

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[7] Hejna M., Gottardo D., Baldi A., Dell'Orto V., Cheli F., Zaninelli M., Rossi L. Review: Nutritional Ecology of Heavy Metals. *Animal.* 2018. Vol. 12. P. 2156–2170.

[8] Goff J.P. Invited Review: Mineral Absorption Mechanisms, Mineral Interactions That Affect Acid–Base and Antioxidant Status, and Diet Considerations to Improve Mineral Status. *J. Dairy Sci.* 2018. Vol. 101. P. 2763–2813.

[9] Слівінська Л.Г. Еритроцитопоез та обмін заліза у тільних корів. *Вісник Білоцерків. держ. аграр. ун-ту*. 2006. № 40. С. 182–188.

[10] Spears J.W. Kegley E.B., Mullis Z.A. Bioavailability of coopfer from tribasic copper chloride and coopfer sulfate in growing cattle. *Anim. Feed Sci. Technol*. 2004. Vol. 116 (1–2). P. 1–13.

[11] El-Sisy, G. A., A. M. A. Abdel-Razek, A. A. Younis, A. M. Ghallab, and M. S. S. Abdou. Effect of dietary zinc or Selenium supplementation on some reproductive hormone levels in male Baladi Goats. *Global Vet.* 2008. Vol. 2 (2). P. 46–50.

(18.75% of animals with anemia each), less – in Ternopil and Volyn regions [12].

Table 1

Prevalence of nutritional-deficiency anemia in western regions of Ukraine

Parameter	Lviv	Ternopil	Ivano-Frankivsk	Volyn	Total
Oligochromemia+ Oligocythemia	15 / 7	11 / 27,5	6 / 15	25 / 62,5	57 / 35,6
Only oligochromemia	1 / 2,5	1 / 2,5	8 / 20	15 / 37,5	25 / 15,6
Only oligocythemia	–	–	2 / 5	–	2 / 1,25
Animals with anemia	16 / 40	12 / 30	16 / 40	40 / 100	84 / 52,5

Out of 160 examined cows, it was noted that 84 were diagnosed with anemia. Hemoglobin content in sick cows ranged from 67.9 to 94.3 g/l (84.9±0.59 on average). It was lower ($p<0.001$) by 14.8% than in healthy cows (Table 2), in which the average indicator was also not too high (99.6±0.53 g/l).

The number of erythrocytes in cows with anemia ranged from 3.4 to 5.8 T/l and was lower ($p<0.001$) than in healthy cows (the difference is 14.5%).Among cows with anemia, oligocythemia was established in 59 animals. Erythrocytes hemoglobin saturation in cows with anemia does not differ from healthy ones ($p<0.5$). The average volume of erythrocytes in healthy cows is lower ($p<0.001$) than in sick cows, but the hematocrit value is 3.8% higher ($p<0.001$), which is explained by a larger number of erythrocytes, not their volume [13].

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[12] Левченко В.І., Слівінська Л.Г. Поширення аліментарно-дефіцитної анемії у корів у Західних областях України. *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2010. Т. 12. № 3 (45). С. 190–196.

[13] Слівінська Л.Г. Еритроцитопоез та обмін заліза у тільних корів. *Вісник Білоцерків. держ. аграр. ун-ту.* 2006. № 40. С. 182–188.

Table 2

Hemopoesis parameters in cows with nutritional-deficiency anemia

Cows group	Hemoglobin g/l	Erythrocytes T/l	*MCH, pg*	Hematocrit, %	*MCV*, Mc/м^3
Healthy (n=76)	95,1–110,5 99,6±0,53	5,0–7,1 5,5±0,10	14,1–22,6 18,1±0,34	25,0–36,8 30,4±0,47	47,0–61,6 52,3±0,33
With anemia (n=84)	67,9–94,3 84,9±0,59	3,4–5,8 4,7±0,045	14,1–22,6 18,2±0,20	23,4–32,2 26,6±0,24	50,1–70,5 57,2±0,26
p<	0,001	0,001	0,5	0,001	0,001

Hematological parameters in animals depend on several factors: breed, body physiological condition, age, maintenance, feeding, etc. Cows pregnancy, especially final period is the critical condition which affects their physiological state and metabolism and affected by various exogenous and endogenous factors. Intensive use of the body's internal reserves to compensate for the lack of feed nutrients leads to significant metabolic disorders, which are significantly worsened and complicated by the deficiency of certain macro- and microelements in the animal body [14].

In addition to the significant difference in hematopoiesis indicators, we analyzed the population composition of erythrocytes in cows suffering from nutritional deficiency anemia and healthy cows (25 cows in each group). The results are presented in Table 3.

As can be seen from the study results presented in Table 3, there is no significant difference in the ratio of the populations of "old" and "young" erythrocytes in cows suffering from anemia, compared to healthy ones, but sick cows have a larger ($p<0.001$) share of "mature" erythrocytes. The number of individual populations differs ($p<0.001$), as it depends on the total number of erythrocytes.

Taking into account the above, we conducted a study of the blood of pregnant cows of the private agricultural enterprise of the Kitsman district of Chernivtsi region, depending on their age and physiological state.

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[14] Левченко В.І., Безух В.М., Сахнюк В.В. Доклінічний перебіг метаболічних хвороб. *Вісник Білоцерків. держ. аграр. ун-ту.* 2001. № 16. С. 115–120.

Table 3

Population composition of erythrocytes in cows with nutritional-deficiency anemia

Parameter	Units of measurement	Healthy	With anemia	p<
Hemoglobin	g/l	95,1–109,9 100,7±0,70	67,9–89,4 82,7±1,14	0,001
Erythrocytes	T/l	5,00–5,98 5,4±0,06	3,40–4,85 4,26±0,081	0,001
"old" erythrocytes	%	10,0–15,9 13,4±0,28	10,2–15,9 12,6±0,33	0,1
	T/l	0,55–0,84 0,72±0,016	0,37–0,62 0,53±0,011	0,001
"mature" erythrocytes	%	38,6–42,4 40,0±0,22	39,2–71,4 42,4±0,22	0,001
	T/l	1,96–2,48 2,15±0,03	1,41–3,37 1,81±0,074	0,001
"young" erythrocytes	%	43,6–49,5 46,6±0,321	16,1–49,7 45,0±1,29	0,5
	T/l	2,21–2,83 2,50±0,037	0,76–2,38 1,92±0,07	0,001

Table 4

General clinical indicators of hematopoiesis in pregnant cows

Indicators	Lactation number							
	1st		2nd		3rd		6th	
	Months of pregnancy							
	5–7	8–9	5–7	8–9	5–7	8–9	5–7	8–9
Redbloodcells, T/l	3,4±0,06 3,0–4,1	3,1±0,03*** 2,9–3,2	3,6±0,04 3,3–4,1	3,7±0,07 3,3–4,2	3,1±0,02 2,9–3,4	3,2±0,05* 3,0–3,7	3,2±0,04 2,9–3,5	3,5±0,06*** 3,0–3,8
Hemoglobin, g/l	102,0±0,88 92,0–108,0	96,5±0,37*** 94,0–99,0	106,4±0,87 98,0–115,0	103,7±1,74 92,0–116,0	95,3±1,15 84,5–104,0	92,5±1,45 85,8–105,4	102,6±1,41 92,8–116,0	103,3±1,21 98,0–116,0
Hematocrit, %	28,0±0,33 25,0–31,0	27,0±0,52 24,0–31,0	28,5±0,32 25,0–31,0	27,2±0,53* 24,0–31,0	23,7±0,25 21,3–27,0	29,4±0,87*** 20,1–26,8	25,5±0,40 22,0–29,0	26,3±0,41 23,0–29,0
MCH, pg	30,0±0,41 26,3–34,0	31,6±0,23** 30,0–33,5	29,0±0,20 26,1–30,3	28,2±0,18** 26,8–29,7	30,7±0,25 28,2–32,4	29,4±0,87 26,5–34,0	32,2±0,35 29,6–36,0	29,8±0,46*** 27,0–33,3
MCV, μm^3	82,0±1,00 73,2–93,7	88,03±1,09*** 79,3–96,9	78,3±0,75 69,4–83,8	73,9±0,21*** 72,7–75,6	76,1±0,63 71,0–81,8	73,1±2,32 61,7–86,5	80,0±1,11 68,8–90,0	75,0±0,68* 70,3–79,4

Notes: * $p < 0,05$; ** $p < 0,01$; *** $p < 0,001$; ^{o} $p < 0,05$; ^{oo} $p < 0,01$; ^{ooo} $p < 0,001$; * – compared between months of pregnancy during lactation; ^{o} – compared between lactation periods.

The analysis of indicators of hemoglobin content in the blood of dry cows shows that in the last months of pregnancy, there is a tendency to the indicator decrease in cows of the 2nd and 3rd lactations. In cows with 1st lactation at 8–9 months of gestation, the hemoglobin content was lower ($p<0.001$; Table 3) than before the start [15]. The latter is obviously due to the fact that in cows with 1st pregnancy it causes stress. In cows of the sixth lactation, both lactating cows (5–7 months) and dry cows (8–9 months), the hemoglobin concentration does not differ among them and is within thephysiological range.

The lowest average level of hemoglobin was found in cows of the third lactation on the 8th-9th (92.5±1.45 g/l) month of gestation, as cows of this age had the highest level of milk productivity.

The amount of erythrocytes in pregnant lactating cows and dry cows and in none of the groups, compared to the periods of lactation and months of gestation, did not reach the lower limit of physiological range (5.0 T/l). Animals in the second lactation have the highest indicators of the number of erythrocytes (3.3–4.2 T/l). This indicator was the lowest in cows of the third lactation, both lactating and dry cows (3.1±0.02, 3.2±0.05 T/l; Table 4).

This can be explained by the fact that cows in the 3rd lactation have the highest level of milk productivity, so by the time of the start, the number of erythrocytes was low. Starting from the 8th month of gestation, nutrients are used by the body for the growth and development of the fetus, and not for the production of milk, so the number of erythrocytes increased. Therefore, oligocythemia was established in cows, regardless of their age, lactation and gestation period.

The hematocrit value was low in all groups of studied cows: it reached a maximum of 31% and was less than the lower limit of the normal range (35%), regardless of age and month of gestation (Table 4).

During the pregnancy period, the saturation of erythrocytes with hemoglobin (*MCH*) in the cows of the studied groups was significantly higher than the normal value (15–20 pg), which is a sign of the development of hyperchromic anemia in lactating and dry cows (Table 4). As a rule, it is a consequence of hypocobaltosis.

The average volume of erythrocytes in different months of gestation and periods of lactation in cows was increased by 2–2.5 times, which is characteristic of macrocytosis (Table 4).

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[15] Слівінська Л.Г. Еритроцитопоез та обмін заліза у тільних корів. *Вісник Білоцерків. держ. аграр. ун-ту.* 2006. № 40. С. 182–188.

At the same time, we studied the metabolism of iron, which deficiency is one of the causes of anemia in animals. We established that the concentration of iron in the blood serum of pregnant cows fluctuated within physiological normal range (Table 5).

Determining the content of ferrum in the blood serum gives an idea only about the level of its transport form in the blood plasma, which is related to transferrin. Therefore, to establish the nature of iron metabolism disorders, it is generally accepted to use, in addition to the level of serum iron, such tests as the total iron-binding capacity of the serum (TIBC), the latent iron-binding capacity (LIBC) of the blood serum, transferrin and its saturation with iron (Table 5).

On the basis of the analysis and biochemistry parameters of the pregnant cows blood there can be established that anemia detected in animals was not caused by the lack of iron because the level of transferring iron saturation was at the level 29.3±1.2–38.2±1.3%, the concentration of transferrin – 2.25±0.90–3.45±0.15 g/l [16].

The dynamics of the erythrotogram indicates the development of hyperchromic macrocytic anemia in pregnant cows, which can be caused by a lack of cobalt, which stimulates erythrocytopoiesis, affecting the conversion of folic acid into tetrahydrofolic acid, which accelerates the maturation of erythrocytes.

In case of a lack of cyanocobalamin, this process is disrupted, because DNA synthesis in hematopoietic organs, in particular, in erythro- and normoblasts, is reduced, their division and maturation is delayed [17] [18].

At the same time, the synthesis of hemoglobin was less disturbed, since this indicator is affected by copper and iron.

The lack of cobalt is also indicated by the results of the research of the feed microelements content, in which we noted a low content of Co (43.6%) and a high Fe (677.6%)[19]. Therefore, in order to clarify the

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[16] Слівінська Л.Г. Еритроцитопоез та обмін заліза у тільних корів. *Вісник Білоцерків. держ. аграр. ун-ту.* 2006. № 40. С. 182–188.

[17] Судаков М., Береза В., Погурський І. Гіпокобальтоз: діагностика і профілактика в біогеохімічних провінціях України. *Вет. медицина України*. 2000. № 8. С. 6–37.

[18] Shcherbatyy, A., Slivinska, L., & Lukashchuk, B. Hypocobaltosis and hypocuprosis in pregnant mares in the western biogeochemical zone of Ukraine (distribution, diagnosis). *Ukrainian Journal of Veterinary and Agricultural Sciences.* 2018. Vol. 1 (2). С. 11-14.

[19] Слівінська Л.Г. Поживність кормів та мінеральний склад раціону тільних корів ПСП "Мамаївське" Чернівецької області. Сільський господар. 2006. № 11–12. С. 34–36.

etiological factor of the anemia occurrence in pregnant cows at this farm, we conducted a study of the metabolism of cobalt and folic acid.

Table 5

Parameters of iron metabolism in pregnant cows

Months of lactation	Iron, Mcmol/l	TIBC, Mcmol/l	LIBC, Mcmol/l	Transferrin iron saturation, %	Transferrin, g/l
1st lactation					
V	23,2±0,61	67,6±1,6	42,4±1,3	34,3±1,4	3,02±0,12
VI	21,1±0,63	71,9±1,9	48,8±1,4	29,3±1,2	3,21±0,13
VII	25,2±0,72	65,9±1,7	38,7±1,1	38,2±1,3	2,94±0,11
VIII	22,4±0,67	64,9±1,5	40,5±1,2	34,5±1,3	2,89±0,10
IX	25,1±0,74	77,3±2,0	50,2±1,4	32,5±1,2	3,45±0,15
2nd lactation					
V	25,1±0,75	69,5±1,9	42,4±1,2	36,1±1,4	3,10±0,11
VI	21,3±0,64	69,7±2,0	46,4±1,3	30,6±1,1	3,11±0,10
VII	23,2±0,70	73,1±2,1	47,9±1,3	31,7±1,1	3,27±0,12
VIII	19,4±0,50	56,1±1,6	34,7±1,0	34,6±1,3	2,51±0,90
IX	24,2±0,68	74,3±1,9	48,1±1,2	32,6±1,2	3,32±0,13
3rd lactation					
V	20,3±0,57	54,6±1,4	32,3±1,0	37,2±1,5	2,44±0,90
VI	18,4±0,49	52,8±1,3	32,4±0,9	34,8±1,4	2,36±0,80
VII	23,1±0,68	75,6±2,2	50,5±1,4	30,1±1,0	3,38±0,14
VIII	21,4±0,63	58,3±1,7	34,9±1,1	36,7±1,3	2,60±0,90
IX	18,5±0,51	50,4±1,2	29,9±0,9	36,7±1,4	2,25±0,90
6th lactation					
V	19,4±0,66	60,2±1,6	38,8±1,1	32,0±1,2	2,69±0,90
VI	23,2±0,75	67,8±1,7	42,6±1,4	34,2±1,3	3,03±0,12
VII	17,8±0,51	51,3±1,4	31,5±1,2	34,7±1,3	2,29±0,10
VIII	20,1±0,80	64,7±1,8	42,6±1,3	31,1±1,1	2,89±0,14
IX	18,2±0,44	51,4±1,2	31,1±1,0	35,5±1,5	2,29±0,13

In cows of the 1st–3rd and 6th lactations in the conditions of the western biogeochemical zone, we established hypoplastic anemia, which is characterized by oligocythemia, hyperchromia, and macrocytosis. The content of iron and transferrin, transferrin iron saturation were within normal limits. This suggests that the primary cause of anemia is cobalt deficiency, not iron deficiency [20].

Soil research conducted by us in Lviv, Ternopil, Ivano-Frankivsk, Chernivtsi, and Volyn regions showed that the amount of Co was 3.6, respectively; 2.1; 2,3; 2.15 and 2.6 mg/kg for optimal – 7–30 [21]

According to some authors, the content of mineral elements in grown forage crops does not necessarily reflect their presence in the soil cover. Complex mechanisms that control the distribution of microelements in the system "weather – soil – plant" do not always determine the correlation between the level of chemical elements in soils and plants. And yet, the content of cobalt in 1 kg of soil is less than 3 mg, causing its lack in plants. At the same time, according to the results we obtained, only in the soils of the Lviv region cobalt is more than 3 mg/kg. The assimilation of cobalt by plants is affected by soil pH: in alkaline soils, the mobility of cobalt and its absorption by plants decrease [22].

Unlike cobalt, the effect of soil pH on cuprum uptake is much smaller, and yet it is more available to plants at low pH than at high pH [23]. Our research established a low Cu content (optimally 2.5–4.0 mg/kg) in the soils of Lviv (0.68 mg/kg) and Volyn (0.79 mg/kg) regions. At the same time the content of the element corresponded to the optimal amount in the soils of Ternopil (3.62 mg/kg), Chernivtsi (2.9 mg/kg), and Ivano-Frankivsk (4.68 mg/kg) regions,

Pregnancy is the special condition of the animal body, during which the general metabolism of substances and energy increases due to the increase in the intensity of these processes in both the mother's and the fetus's body. During the calving period, the cow's body feels a special need

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[20] Слівінська Л.Г. Еритроцитопоез та обмін заліза у тільних корів. *Вісник Білоцерків. держ. аграр. ун-ту.* 2006. № 40. С. 182–188.

[21] Левченко В.І., Слівінська Л.Г. Поширення аліментарно-дефіцитної анемії у корів у Західних областях України. *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2010. Т. 12. № 3 (45). С. 190–196.

[22] House W.F. Bell A.W. Mineral accretion in the fetus and adnexa during late gestation in Holstein Cows. *J. Dairy Sci.* 2001. Vol. 84 (1). P. 225–232.

[23] Лизогуб М., Кондрахін І. Зв’язок вмісту міді та цинку в ланцюгу: грунт-корми-тварина. *Вет. медицина України*. 1997. № 5. С. 24.

for biogenic microelements. For example, in the first months of pregnancy (<100 days), approximately 0.5 mg of copper enters the fetus, placenta, and uterus, and at the end of pregnancy – 1.5-2 mg[24].

Complete and nutritionally balanced feeding of pregnant cows is a decisive factor in their productivity, as well as obtaining healthy offspring. In addition to basic nutrients, mineral nutrition is important, since most macro- and microelements are part of the organs and tissues of the animal body, directly affect metabolic processes and the state of hematopoiesis [25].

Therefore we conducted the analysis of the rations of pregnant cows during winter-stalling period, examined the feeds for the content of micro-elements at six farms, located in various biogeochemical zones of western region. Studies were conducted at dry cows of Ukrainian black- and red-pitted breed aged from 2 to 8 years old, productivity 6000-8000 kg.

In the structure of the diet of farms of the zones of the Western region (in terms of metabolic energy), the share of concentrated feeds is 19.4–20.3%, forage and succulent feeds, respectively, 23.9–38.1 and 41.8–56.2%.

The analysis of the rations of dry cows from farms during the winter-stalling period showed that they are mostly balanced in terms of nutrition, metabolic energy, sugar-protein ratio, but in all farms there is an excess of dry matter, fiber, iron and a lack of cobalt, copper, iodine and zinc.

The important stage of studying of the animals supply with nutrients and bioactive substances (BAS) is the analysis of their content in the ration dry matter 1 kg. The analysis of the studies results demonstrated the deficiency of the general amount of micro-elements, except for the iron and manganese, which is the basis for the development of microelementosis based on the lack of one or more of the five named vital elements, at the studied farms. However, it should be taken into account that micro-element deficiency can occur not only in those animals located in a certain biogeochemical zone, but also due to increased needs of the body during pregnancy, high milk productivity, and intensive use of animals in the conditions of industrial technology for the production of livestock products.

So, we found that the main reasons for the development of alimentary anemia in dry cows were the low content of Co, Cu and J in the vast

[24] House W.F. Bell A.W. Mineral accretion in the fetus and adnexa during late gestation in Holstein Cows. *J. Dairy Sci.* 2001. Vol. 84 (1). P. 225–232.

[25] Pernes G., Michelle C.F., Lancaster I.G., Murphy J.A. Fat for fuel: lipid metabolism in haematopoiesis. *Clin. Transl. Immunology.* 2019. Vol. 8 (12). P. 1098.

majority of rations, their low concentration in 1 kg of dry matter, and hence the insufficient level of their supply to the body. The concentration of cobalt is especially low: 2.5 times less (0.19–0.25 mg/kg) than the minimum (0.55 mg/kg).

The detected deficiency of essential microelements in feed requires additional introduction of appropriate microelements or special microelement premixes into the diet of animals.

Thus, the analysis of the provision of feed with microelements and their inclusion in the diet will allow to eliminate the deficiency and imbalance of microelements in the animal body, metabolic disorders and affect the productivity of animals.

2. Acid resistance and age-related erythrocytes composition in cows with nutritional-defificiency anemia

Postnatal development of animals is accompanied by structural and functional changes in organs and systems aimed at creating optimal conditions for the development of the organism. An important role in this process belongs to the blood system, one of the components of which are erythrocytes[26]. However, until now, when studying erythrocytopoiesis in human and veterinary medicine, the quantitative approach dominates, and the qualitative composition of the erythrocyte population, their resistance to mechanical, chemical, osmotic, isothermal, and other factors is studied extremely rarely. In the literature, there are reports on the peculiarities of erythrocyte formation and metabolism of erythroid cells of pigs, horses, foals and newborn calves, high-yielding cows due to pathologies of internal organs[27], mineral and lipid composition and properties of erythrocyte membranes due to D-hypovitaminosis, anemia and bronchopneumonia in calves.

As noted by literary sources, as cells age, their lipoproteins become depleted, the sulfhydryl and peroxidase activity of protoplasm decreases, and the content of histidine and lipids partially changes. In such cells, the intensity of lipid peroxidation increases, which leads to the development of destructive processes in plasma membranes and disruption of the transport system of cations and amino acids.

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[26] Xia Q., Zhang Y., Li Z. Red blood cell membrane-camouflaged nanoparticles: a novel drug delivery system for antitumor application. *Acta Pharm Sin B.* 2019. Vol. 9. P. 675–89.

[27] Левченко В.І., Сахнюк В.В., Москаленко В.П. Популяційний склад і властивості еритроцитів у високопродуктивних корів. *Вісник аграрної науки*. 2004. № 10. С. 41–44.

Therefore, the study of the functional state of the population composition and acid resistance of erythrocyte membranes during nutritional deficiency anemia in cows from different regions of the western region of Ukraine is relevant.

The analysis of the results of the fractionation of peripheral blood in the sucrose density gradient shows that the blood of dry cows of all regions consists mostly of populations of "old" and "mature" erythrocytes, the number of "young" is slightly less than half and on average was from 45.3±0.52 to 48.4±0.43% (Table 6).

The age composition of erythrocytes in the blood of pregnant cows in individual regions differs slightly. For example, the population of "old" erythrocytes is the largest in cows of Ivano-Frankivsk region (14.2±0.39%), the smallest – in the cows of Lviv (11.8±0.42) and Volyn (11.9±0.42%) regions, but even in the cows of Ternopil region, the proportion of "old" erythrocytes (12.6±0.43%) was probably ($p<0.05$) lower than in Ivano-Frankivsk region.

At the same time, the share of "young" erythrocyte populations in cows of Ternopil region is 1.9% higher ($p<0.05$) compared to Ivano-Frankivsk region [28].

A similar tendency was found in the analysis of the dynamics of the population composition of the blood of cows of Lviv region.

It is characterized by a probable ($p<0.001$) decrease by 2.4% of the number of "old" cells (their content was 11.8±0.42% on average) and an increase ($p<0.01$) by 3.1% – " young" (48.4±0.43% compared to Ivano-Frankivsk region.

The dynamics of the population composition of erythrocytes of cows of Volyn region is characterized by a tendency of "old" erythrocytes decrease, but it probably did not differ from Ternopil and Lviv regions and was on average 11.9±0.42%, but the difference was probably smaller ($p<0.05$) with Ivano-Frankivsk region.

The population of "young" erythrocytes had only a tendency to increase and amounted to an average of 46.4±0.90%.

The population of "mature" erythrocytes was characterized by stability in all regions and averaged 39.8±0.43%; 40.2±0.29; 40.5±0.39; 41.7±0.49%, respectively, in Lviv, Ternopil, Ivano-Frankivsk, and Rivne regions. There was a significant difference between the first and last regions ($p<0.05$).

[28] Слівінська Л.Г. Структурно-функціональні властивості еритроцитів за анемії різної етіології. *Вісник Білоцерків. нац. ун-ту.* 2009. № 62. С. 81−87.

Таблиця 6

Population composition of cows erythrocytes in the farms of the western region

Name of regions	Biometric indicator	"Old"		"Mature"		"Young"	
		%	Т/л	%	Т/л	%	Т/л
Lviv region (n=10)	Lim M±m	10,2–14,1 11,8±0,42	0,37–0,89 0,64±0,042	37,8–41,7 39,8±0,43	1,45–2,76 2,18±0,131	45,9–50,3 48,4±0,43	1,79–3,14 2,63±0,1209
Ternopil region (n=10)	Lim M±m	10,7–14,8 12,6±0,43	0,48–0,91 0,65±0,041	38,7–41,4 40,2±0,29	1,69–2,41 2,06±0,068	44,6–49,5 47,2±0,46	1,94–2,79 2,43±0,089
Ivano-Frankivsk region (n=10)	Lim M±m	12,2–15,9 14,2±0,39	0,59–0,84 0,72±0,028	38,6–42,4 40,5±0,39	1,81–2,22 2,04±0,038	43,6–48,9 45,3±0,52	2,06–2,47 2,30±0,047
Volyn region (n=10)	Lim M±m	10,5–14,6 11,9±0,42	0,50–0,74 0,58±0,025	39,7–43,9 41,7±0,49	1,77–2,23 2,03±0,042	43,9–50,1 46,4±0,90	2,06–2,44 2,25±0,044

In addition to the analysis by regions, we compared the population composition of erythrocytes depending on the level of hemoglobin and erythrocytes. In cows with anemia (Table 7), the share of the population of old erythrocytes did not differ from the indicator in hematologically ill ($p<0.1$), but their absolute number was probably smaller (0.53±0.011 T/l, compared to 0.72±0.016 – in healthy people).

Table 7

Population composition of erythrocytes in cows with alimentary deficiency anemia

Group of cows	Biometric indicator	"Old" erythrocytes	"Mature" erythrocytes	"Young" erythrocytes
Healthy	Lim	10,4–15,9	38,6–42,4	43,6–49,5
	M±m	13,4±0,28	40,0±0,22	46,6±0,34
Ill	Lim	10,2–15,9	40,2–46,5	40–48,7
	M±m	12,6±0,33	42,4±0,22	45,0±0,48
	p<	0,1	0,001	0,01

In cows suffering from anemia, the share of the population of "mature" erythrocytes increases (+2.4%), which indicates a more intensive maturation of them and their release into the bloodstream ($p<0.001$). At the same time, the share of "young" erythrocytes in them is somewhat lower (by 1.6%; $p<0.01$) than in healthy cows.

Due to the decrease in the total number of erythrocytes in the bloodstream of cows with anemia (4.7±0.045, compared to 5.5±0.10 T/l in healthy cows), the absolute number of erythrocytes in the population of "mature" and "young " erythrocytes is less than healthy erythrocytes.

The acid erythrogram, built on the determination of the distribution according to the resistance of peripheral blood erythrocytes to hemolysis, reflects the state of the blood system and reacts with natural changes to the departure of this system from equilibrium, i.e., mainly indicates the connection between the resistance and the age composition of erythrocytes[29].

The hemolysis of erythrocytes depends on the time required for the hemolytic to overcome the barrier of membrane impermeability, the rate of destruction of intracellular structures, and the time during which the mechanical strength of the membrane resists the increasing osmotic pressure inside the cell[30].

Since acid resistance depends on the age of erythrocytes, the dynamics of their acid resistance in farm cows have been studied. The erythrogram of dry cows of the Volyn region was characterized by a pronounced peak of hemolysis at the third minute, which was 15.9%. Haemolysis of erythrocytes was completed in 6.5 minutes, which is faster compared to Ternopil and Lviv regions, respectively, by 1.0 and 1.5 minutes (Fig.1), since the number of young erythrocytes is more significant in these regions, especially in Lviv region.

The analysis of the graphic image of the acid resistance of erythrocytes of dry cows of the Ivano-Frankivsk region shows that their principal peak came at 4 minutes; its height was 1.8% less than in the Volyn region and was 14.1%. Hemolysis of erythrocytes also ended at 6.5 minutes.

The output of the principal peak in the cows of the Ternopil region occurred at 4.5 minutes, and the height of the central peak was 2.0% lower, compared to the animals of the Ivano-Frankivsk region, by 3.8% – in the Volyn region, and was 12.1%. Hemolysis ended in 7.5 minutes.

Acid resistance of erythrocytes in animals of the Lviv region is characterized by a hemolysis peak of 12.1%. If the structure of the erythrogram in cows from the Lviv and Ternopil regions was similar, hemolysis was completed in these animals 1.0 minutes later than in cows from the Volyn and Ivano-Frankivsk regions.

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[29] Paiano R.B., Birgel D.B., Birgel Junior E.H. Influence of peripartum on the erythrogram of Holstein dairy cows. *J. S. Afr.Vet. Assoc*. 2020. Vol. 91. P. 1975.

[30] Köhne I. Haemolysis induced by mechanical circulatory support devices: unsolved problems. *Perfusion.* 2020. Vol. 35 (6). P. 474-483.

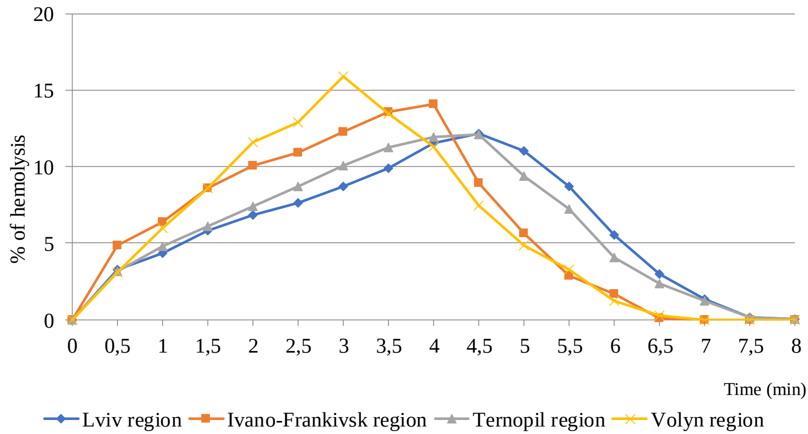

Fig. 1. Acid resistance of erythrocytes in healthy and sick cows with nutritional deficiency anemia

The reduction in hemolysis time depends on the resistance of erythrocytes to the hemolytic agent and, therefore, on the erythrocyte's age. Thus, the shift of the peak of the erythrogram to the right in the blood of cows of the Ternopil and Lviv regions indicates a high content in the vascular bed of the population of "young" erythrocytes, the most resistant to hemolysis.

In our opinion, the low content of "old" and probably higher "young" erythrocytes in the blood of cows of the Ternopil, Ivano-Frankivsk, and Lviv regions is a compensatory phenomenon. It is known that under hypoxia, a pathogenetic link to anemia, irritation of the bone marrow occurs, and young, immature erythrocytes enter the blood, which partially compensates for the lack of oxygen and excess carbon dioxide in the body of dry cows with nutritional deficiency anemia.

3. The content of trace elements and vitamin B_{12} in the blood of cows with nutritional deficiency anemia

We have established a low content of several microelements in fodder and rations and cows' blood that participate in the body's metabolic processes. A decrease in the content of cobalt and copper in the blood of cows is due to their insufficient content in the soil and feed[31], as well as a violation of the ratio between individual trace elements and their antagonistic interactions in the body [32] [33]. In addition, their decrease may be related to body size and the lactation period in cows since part of the microelements is excreted with milk.

However, the western biogeochemical zone differs in the content of essential elements in soils, feed, and, as a result, in the body of cows. Therefore, we decided to summarize the results obtained in different areas and calculate confidence intervals for each element (copper, cobalt) and cyanocobalamin.

Copper plays an essential role in hematopoiesis. It enhances the mobilization of deposited Ferrum in the bone marrow, catalyzes its inclusion in the heme structure, and promotes the maturation of erythrocytes in the early stages of development [34]. In addition, copper is part of oxidizing enzymes: ceruloplasmin, cytochrome oxidase, superoxide dismutase, galactose oxidase, and others, which catalyze individual stages of tissue respiration and participate in exchange processes, contribute to the protection of lipid membranes from peroxide oxidation[35]. Therefore, for the western biogeochemical zone, it is essential to control the content of copper in diets and blood.

We investigated the amount of this bio element in the blood serum of 80 cows: 20 cows in each of the regions (Lviv, Ternopil, Ivano-Frankivsk, and Volyn). The average content of copper in all regions was 11.7±0.243 µmol/l with fluctuations of 10.7±0.37 – 12.4±0.63 µmol/l (Table 8). Cows from the Volyn region had the least amount of copper, while cows from the Lviv region had the most. The difference between their indicators is probable ($p<0.05$). The same degree of probability of

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[31] Слівінська Л.Г. Поживність кормів та мінеральний склад раціону тільних корів ПСП "Мамаївське" Чернівецької області. *Сільський господар*. 2006. № 11–12. С. 34–36.

[32] Jaskowski J. Desorpcja jonow miedzi w zroznicowanych warunkach glebowych. *Mikcroelementy w rolnictwie*. 2002. Vol. 1. P. 83–88.

[33] Sharma M.C., Joshi C., Pathak N.N., Kaur H. Copper status and enzyme, hormone, vitamin and immune function in heifers. *Res. Vet. Sci*. 2005. Vol. 79 (2). P. 113–123.

[34] Сологуб Л.І., Антоняк Г.Л., Стефанишин О.М. Роль міді в організмі тварин. *Біологія тварин*. 2004. Т. 6. № 1–2. С. 64–76.

[35] Alagawany M., Elnesr S.S., Farag M.R., Tiwari R., Yatoo M.I., Karthik K., Michalak I., Dhama K. Nutritional significance of amino acids, vitamins and minerals as nutraceuticals in poultry production and health – a comprehensive review. *Vet Q*. 2020. Vol. 41 (1). P. 1–29.

the difference in copper content in cows of the Volyn and Ivano-Frankivsk regions. The copper content of cows from the Ternopil region did not differ from cows from other regions of the western region of Ukraine.

When determining the content of copper, we found that it was 24.5% lower than the lower limit of physiological fluctuations (12.6 – 18.4 μmol/l) in the blood of dry cows of the Volyn region and was on average 10.7±1.60 μmol / l. The content of copper in the blood of experimental animals of the Lviv region ranged from 8.8 to 17.69 μmol/l, and in 15 cows (75%), it exceeded the minimum physiological limit (Table 8). In 19 (95%) cows from Ternopil and 17 (85%) from 20 Ivano-Frankivsk regions, the copper content was lower than 14.1 μmol/l. Therefore, we found a low trace element level in the blood of cows of the Volyn, Lviv, Ternopil, and Ivano-Frankivsk regions.

According to the literature[36], copper in the blood serum of cows should be 12.6–18.9 μmol/l (according to others – 14.1–17.3 μmol/l). If we take into account even the minimum indicator (12.6 μmol/l), then we found a decrease in the content of copper in the blood in 58 cows out of 80 (72.5%), the largest – in Volyn (90%), the least – in Lviv (55 %) regions.

Thus, on a rather significant herd of cows, we established hypocupremia in 72.5% of cows, which is one of the causes of nutritional deficiency anemia.

The value of the mean square deviation (r) for copper is ±1.8 μmol/l, but only in 56.2% of cows are its limits included in these intervals; at the same time, in the confidence intervals M±2σ – 100% of cows (8, 2 – 15.3 μmol/l). Thus, for the western biogeochemical zone, copper fluctuations can be 8.2 – 15.3 μmol/l (11.7±0.24).

The content of cobalt in different regions differed slightly and was in the range from 0.18 to 0.61 μmol/l (on average 0.38±0.011), that is, within limits much smaller than the literature values (0.50 – 0.85 μmol/l). The least amount of cobalt and copper was found in cows from the Volyn region (0.31±0.019 μmol/l). In the rest of the regions' cows, the cobalt content difference was probable. In the blood of the cows of the Ternopil region, cobalt was probably ($p<0.05$) more compared to the indicator in the cows not only of the Volyn region but also of the Lviv and Ivano-Frankivsk regions (Table 8).

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[36] Влізло В.В., Сологуб Л.І., Янович В.Г., Антоняк Г.Л., Янович Д.О. Біохімічні основи нормування мінерального живлення великої рогатої худоби. 2. Мікроелементи. *Біологія тварин*. 2006. Т. 8. №. 1–2. С. 41–62.

Table 8

The content of cobalt, copper, and vitamin B_{12} in the blood of dry feeding cows on the farms of the western region of Ukraine

Indicator	Biometric indicator	Regions			
		Volyn, n=20	Lviv, n=20	Ivano-Frankivsk, n=20	Ternopil, n=20
Cuprum, μmol/l	Lim M±m	8,19–13,98 10,7±0,37	8,85–17,69 12,4±0,63*	9,45–15,19 11,9±0,41	8,61–14,72 11,7±0,38
Cobalt, μmol/l	Lim M±m	0,18–0,45 0,31±0,019	0,22–0,54 0,38±0,021*	0,20–0,48 0,37±0,018*	0,31–0,61 0,44±0,017**
B_{12} ng/l	Lim M±m	154–241 204,0±5,03	179–290 220,0±7,16	191–312 232,3±7,44	204–386 259,3±10,19

Notes: p< – compared to indicators in the Volyn region, *p<0.05; **p<0.01.

When analyzing individual indicators, we established a low level of cobalt in cows of all regions.

The lowest level of cobalt was in the blood of cows in the Volyn region. Thus, if the physiological limit of cobalt content in the blood plasma of cattle is in the range from 0.50 to 0.85 μmol/l, then in 20 experimental cows of the Volyn region (100%), its level was lower than 0.50 μmol /l, on average for the group was only 0.31±0.019 μmol/l; in 50% of cows, it was less than this indicator.

In experimental cows of the Lviv region, the cobalt content was on average 0.38±0.021 μmol/l, and in only two animals (10%), it reached the lower limit of physiological fluctuations (0.5 μmol/l); in 7 animals (35%) it the content was 1.5 times lower. Therefore, hypocobaltosis is established in 90% of cows.

In the blood of cows of the Ivano-Frankivsk region, the level of cobalt fluctuated within the range of 0.20–0.48 μmol/l and, on average, was 0.37±0.018, which is 27.5% below the minimum standard limit. In all 20 cows, cobalt is less than 0.5 μmol/l.

This indicator was the highest in the blood of dry cows of the Ternopil region – on average 0.44±0.017 μmol/l, although it was within the physiological range in only two cows. Therefore, hypocobaltosis is established in 90% of cows in the Lviv and Ternopil regions and 100% in the Ivano-Frankivsk and Volyn regions.

Calculations of the mean square deviation (σ) obtained from the results of the study of 80 cows showed that the confidence limits of cobalt within M± σ should be 0.28 – 0.48 μmol/l, M±2σ – 0.18 – 0.58 μmol/l These limits cover 78.8 and 98.8% of cows in the western regions of Ukraine, respectively.

The experimental results obtained by us are confirmed by calculations and testify to the inadequate supply of cobalt to cows. The average cobalt content (0.38±0.022 μmol/l) is less than the minimum (0.5 μmol/l).

Simultaneously, cobalt in the body is used in many vital processes: synthesis of vitamin B_{12} and hematopoiesis. Insufficient cobalt supply with feed leads to a violation of the microbial synthesis of cyanocobalamin in the antrum and insufficient absorption into the blood, which causes a negative nitrogen balance and, ultimately, the development of anemia. With a lack of vitamin B_{12}, the conversion of folic acid into its metabolically active form – tetrahydrofolic acid is disrupted, which leads to a decrease in DNA synthesis in erythro- and normoblasts, their release and maturation are delayed, and this contributes to the transformation of normoblastic erythrocytopoiesis into megaloblastic[37] [38] That is why hyperchromic anemia and macrocytosis develop with cobalt deficiency.

According to our results, the vitamin B_{12} in the blood ranged from 154 to 386 pg/ml (or 154 – 386 ng/l) and averaged 230.0±4.36 pg/ml. The lowest amount of cyanocobalamin in the blood of cows of the Volyn region (204.0±5.03 ng/l).

In the blood of cows from the Lviv region, only a trend towards an increase in the content of cyanocobalamin (7.8%) was observed, while in the Ivano-Frankivsk and Ternopil regions – a probably higher amount of vitamin B_{12}, which, to some extent, correlates with the increase in the concentration of cobalt in the cows of the latter two areas.

The analysis of the data we received shows that in the Volyn region, there were 100% of cows with a cyanocobalamin content of less than 250 pg/ml, in the Lviv region – 15 out of 20 (75%), Ivano-Frankivsk region – 14 (70%), Ternopil region – 9 (45%); out of 80 examined cows, 58 (72.5%) had a low vitamin B_{12}.

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[37] Судаков М., Береза В., Погурський І. Гіпокобальтоз: діагностика і профілактика в біогеохімічних провінціях України. *Вет. медицина України*. 2000. № 8. С. 36–37.

[38] Infante M., Leoni M., Caprio M., Fabbri A. Long-term metformin therapy and vitamin B_{12} deficiency: An association to bear in mind. *World J Diabetes*. 2021. Vol. 12 (7). P. 916-931.

Cobalt is necessary for synthesizing vitamin B_{12}, which contains 4% of the bio element. According to the literature[39], ruminants use cobalt inefficiently to synthesize cyanocobalamin. With a deficiency of cobalt in the diet, the synthesis of the biologically active form of vitamin B_{12} is 15% of the total number of compounds containing this element and with an acceptable content in the diet – 3%[40 41]. In addition, absorption of vitamin B_{12} in ruminants is only 3–5% of the dose used. Therefore, it is pretty logical to determine the correlation between the content of cobalt and vitamin B_{12} in the blood of dry cows. Our calculations showed that the correlation coefficient for 80 cows from 4 regions is positive and is +0.67, including for Volyn and Ternopil regions – 0.98, Lviv – 0.81, and only for cows from the Ivano-Frankivsk region – low degree correlation (+ 0.36). A direct relationship with a high degree of probability was established between the content of cobalt and vitamin B_{12} in the blood of cows in 4 regions ($p<0.001$).

Thus, our research has shown that the soils and fodder of the Western biogeochemical zone have a low content of certain essential trace elements, especially cobalt, copper, and zinc. The biggest shortage is cobalt. There is especially little of it in 1 kg of dry matter of the ration of SVC "Ukraine" – 0.19 mg (if necessary – 0.55–0.80). Accordingly, animal diets have a significant deficiency of these trace elements. Availability of copper is 65.5-82.2%, zinc – 40-51.8%, cobalt – 34.5-45.4%, iodine – 43.6-65.4%.

At the same time, there is a significant surplus of Ferrum in the rations of cows of all farms where the work was carried out (supply 677.6; 844.2; 769; 848.8; 774.2; 669.6%), its high concentration in 1 kg of dry substances – 314.8; 399; 382; 405; 337; 306 mg), which is 3.8-5.1 times greater than the maximum (80 mg/kg). According to the literature, the absorption of other essential trace elements (zinc and

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[39] González-Montaña J.R., Escalera-Valente F., Alonso A.J., Lomillos J.M., Robles R., Alonso M.E. Relationship between Vitamin B_{12} and Cobalt Metabolism in Domestic Ruminant. *An Update. Animals (Basel).* 2020. Vol. 10 (10), P. 1855.

[40] Влізло В.В., Сологуб Л.І., Янович В.Г., Антоняк Г.Л., Янович Д.О. Біохімічні основи нормування мінерального живлення великої рогатої худоби. 2. Мікроелементи. *Біологія тварин*. 2006. Т. 8. № 1–2. С. 41–62.

[41] Паска М.З., Личук М.Г. Фізіолого-біохімічні критерії обміну кобальту та вітаміну B_{12} у телят. *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2009. Т. 11. № 3-2 (42). С. 123–126.

copper) may be impaired at a concentration of 250-500 mg of Ferrum in 1 kg of dry matter [42].

Thus, it was essential to find out the content of trace elements in the third link – the blood of animals. We performed this work on 80 cows in four regions of Ukraine. A reduced level of copper was found in the blood of 75% of cows in the Lviv region, 95% in the Ternopil region, 85% in the Ivano-Frankivsk region, and 100% in the Volyn region; cobalt, respectively, in 90%; 90; 100 and 100%. In turn, cobalt deficiency causes a decrease in the synthesis of cyanocobalamin in the body. A positive correlation (r=+0.67) was established between these indicators, exceptionally high (r=0.98) in cows from Volyn and Ternopil and Lviv (r=0.81) regions.

Our analysis of the morphological composition of blood and the content of microelements (Fe, Co, and Cu) in 160 cows showed that the low level of cobalt and copper is a problem in the entire Western region of Ukraine. Therefore, we analyzed the relationship between microelements' content and hematopoiesis indicators. For this purpose, 160 cows were divided into two groups: in one – cows suffering from anemia (n=84), in the other – hematologically healthy cows (n=76).

The content of copper among hematologically healthy cows ranged from 10.5 to 15.6 µmol/l (12.4±0.19), cobalt – 0.292–0.514 µmol/l (0.413±0.013) (Table 9).

Table 9

The content of cobalt and copper in nutritional deficiency anemia, µmol/l

	Biometric indicator	Healthy (n=76)	Patients with anemia (n=84)	p<
Cobalt	Lim	0,292–0,514	0,223–0,480	
	M±m	0,413±0,013	0,326±0,017	0,001
Cuprum	Lim	10,5–15,6	9,3–14,15	
	M±m	12,4±0,19	10,86±0,24	0,001

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[42] Паска М.З., Личук М.Г. Метаболічні реакції організму бугайців поліської м’ясної породи залежно від типів вищої нервової діяльності при згодовуванні кормової добавки «Мікроліповіт». *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2014. Т. 16. № 2 (59). С. 271–277.

In 47 cows out of 76 (61.8%), copper was less than 12.6 μmol/l – the amount considered to be the minimum limit of the norm. The cobalt content in 74 cows (97.4%) was below the physiological limit (0.50 μmol/l). Therefore, even in cows with a hemoglobin content and several erythrocytes within physiological limits, the level of both microelements does not correspond to the indicators that, according to the literature, are optimal [43].

In anemic cows, the content of both essential trace elements was probably ($p<0.001$) lower: copper by 12.4% and cobalt by 21.1%. Only in 8 cows out of 84 (9.5%) the copper content was at the lower limit of normal but did not exceed 14 μmol/l, and the cobalt level was more significant than 0.4 μmol/l but less than 0.5 μmol/l. 11 cows (13.1%). Therefore, in cows suffering from anemia, the level of both MEs is probably lower ($p<0.001$) than in healthy cows (according to the hemoglobin content and the number of erythrocytes).

We calculated the correlation coefficients between the content of Co and Cu and indicators of hematopoiesis. In hematologically healthy cows, a high positive correlation was established between the content of cobalt and hemoglobin ($r=0.795$) and the hematocrit value ($r=0.637$), and a moderate correlation between the content of cobalt and the number of erythrocytes ($r=0.453$) and the average volume of erythrocytes ($r =0.480$). Copper content correlates positively with the number of erythrocytes ($r=0.697$) and hematocrit value ($r=0.669$), the correlation with hemoglobin content is of a low degree ($r=0.383$).

In anemic cows, the cobalt content did not correlate with the hemoglobin content, the number of erythrocytes, the hematocrit value, and the average volume of erythrocytes.

4. Lipid peroxidation and the state of the antioxidant system in cows with nutritional deficiency anemia

Active forms of oxygen (AFO) are standard products of metabolic processes in the body of animals. Superoxide (O_2) and hydrogen peroxide (H_2O_2) are products and substrates in some enzymatic reactions[44]. Under

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[43] Влізло В.В., Сологуб Л.І., Янович В.Г., Антоняк Г.Л., Янович Д.О. Біохімічні основи нормування мінерального живлення великої рогатої худоби. 2. Мікроелементи. *Біологія тварин.* 2006. Т. 8. № 1–2. С. 41–62.

[44] Shcherbatyy, A.R., Slivinska, L.G., Gutyj, B.V., Fedorovych, V.L., Lukashchuk, B.O. Influence of Marmix premix on the state of lipid peroxidation and indices of non-specific resistance of the organism of pregnant mares with microelementosis. *Regulatory Mechanisms in Biosystems*. 2019. Vol. 10. Iss. 1. P.87–91.

certain conditions, harmful forms of oxygen (free radicals and their metabolites) are formed in the body of animals and humans[45]. A small amount of AFO (3%) in the body of animals is formed under physiological conditions in the process of metabolism. However, when the action of pro-oxidant factors exceeds the activity of the antioxidant defense system, increased formation of AFO in the animal body leads to "oxidative" stress.

Among the reactions in which AFO participates in the living system (interaction with lipids, proteins, nucleic acids, and other organic compounds), interaction with proteins is of great importance since post-translational modifications of these protein molecules are one of the links in the mechanism of AFO influence on intracellular metabolism[46].

According to the literature, antioxidant protection in the body of cows largely depends on their physiological state, in particular, on the stage of pregnancy. Such features are due to changes in the hormonal status and metabolic stress in the body of cows during the calving period, especially before calving[47]. This leads to an increase in free radical processes, which negatively affects the physiological state of animals and the development of the fetus[48].

In recent years, POL indicators have been widely used in diagnosing various pathologies in animals because the course of any pathological process in the body depends on its intensity. According to modern ideas, POL is considered, on the one hand, as a physiological process in the animal body that ensures the renewal of cell membranes, and on the other hand, as a violation of the state of the antioxidant defense system (ADS), which causes destructive processes at the cellular level[49].

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[45] Gutyj, B., Stybel, V., Darmohray, L., Lavryshyn, Y., Turko, I., Hachak, Y., Shcherbatyy, A., Bushueva, I., Parchenko, V., Kaplaushenko, A., Krushelnytska, O. Prooxidant-antioxidant balance in the organism of bulls (young cattle) after using cadmium load. *Ukrainian journal of Ecology.* 2017. Vol. 7 (4). P. 589-596.

[46] Влізло В.В., Сологуб Л.І., Янович В.Г., Антоняк Г.Л., Янович Д.О. Біохімічні основи нормування мінерального живлення великої рогатої худоби. 2. Мікроелементи. *Біологія тварин*. 2006. Т. 8. № 1–2. С. 41–62.

[47] Rahdar A., Hasanein P., Bilal M., Beyzaei H., Kyzas G.Z. Quercetin-loaded F127 nanomicelles: Antioxidant activity and protection against renal injury induced by gentamicin in rats. *Life Sci.* 2021. Vol. 276. P. 119420.

[48] Слипанюк О.В. Антоняк Г.Л., Сологуб Л.І. Перекисне окиснення ліпідів і антиоксидантний статус у крові корів у останній місяць тільності. *Біологія тварин*. 2000. № 2(2). С. 83–86.

[49] Зінко Г.О. Пероксидно-окисні процеси та стан системи антиоксидантного захисту у телят за гастроентериту. *Аграрний вісник Причорномор'я.* 2017. № 83. С. 86–90.

The ADS system, one of the animal body's critical regulatory systems, counteracts the POL processes, thus causing the preservation of the structural characteristics of membranes. ADS is a complex of non-enzymatic antioxidants and specialized antioxidant enzymes. Superoxide dismutase (SOD) and glutathione peroxidase (GPO) is particularly important among enzymatic antioxidants. SOD is one of the first links in the mechanisms of cell protection against the harmful effects of active forms of oxygen, neutralizing the superoxide radical, which is the starting point in several free radical transformations. GPO reduces hydrogen peroxide and lipid hydroperoxides [50] [51].

Erythrocytes are characterized by high activity of SOD and GPO [480, 481], where the primary source of superoxide radical is the autooxidation of oxyhemoglobin with the formation of methemoglobin, since for erythrocytes to perform their primary function – oxygen transport – it is necessary to prevent the accumulation of products of free radical reactions in these cells[52].

Based on the above, the next stage of the work was the study of the role of POL processes in the blood of cows and the study of the effect of oxidative stress on the level of SOD and GPO activity in erythrocytes of cows with nutritional deficiency anemia.

According to our research, the concentration of lipid hydroperoxides in the blood plasma of cows with anemia in the studied regions was almost at the same level and was, on average, 1.71±0.059; 1.69±0.042; 1.61±0.038 and 1.65±0.040 Units. E 480/ml, respectively (Table 9).

An important indicator that characterizes the intensity of POL in the blood of animals is the study of the level of diene conjugates (DC). The concentration of DC in cows from different regions of the Western region of Ukraine differed slightly and ranged from 8.46 to 14.45 μmol/l (on average 10.6±0.15). Cows from the Ivano-Frankivsk region had the lowest

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[50] Gutyj B., Stybel V., Darmohray L., Lavryshyn Y., Turko I., Hachak Y., Shcherbatyy A., Bushueva I., Parchenko V., Kaplaushenko A., Krushelnytska O. Prooxidant-antioxidant balance in the organism of bulls (young cattle) after using cadmium load. *Ukrainian journal of Ecology*. 2017. Vol. 7 (4). P. 589–596.

[51] Shcherbatyy A.R., Slivinska L.G., Gutyj B.V., Fedorovych V.L., Lukashchuk, B.O. Influence of Marmix premix on the state of lipid peroxidation and indices of non-specific resistance of the organism of pregnant mares with microelementosis. *Regulatory Mechanisms in Biosystems.* 2019. Vol. 10 (1). P. 87–91.

[52] Slivinska L. G., Shcherbatyy A. R., Lukashchuk B. O. & Gutyj, B. V. The state of antioxidant protection system in cows under the influence of heavy metals. *Regulatory Mechanisms in Biosystems.* 2020. Vol. 11 (2). P. 237–242.

average DC index, but it differed significantly ($p<0.05$) only from the similar one among cows from the Ternopil region (8.1%).

The concentration of malondialdehyde (MDA) – the end product of POL – in anemic cows of the Ternopil region averaged 7.1±0.40 nmol/ml and probably did not differ from the indicators in animals from the Ivano-Frankivsk, Volyn and Lviv regions.

It should be noted that the processes characteristic of oxidative stress occur in the body of dry-feeding cows since the lipid products' lipid content in fat cows' blood reflects the general state of peroxide processes in their tissues.

Table 10

Indicators of the state of the POL-ADS system in dry feeding cows

Indicators of the systems POL-ADS	Biometric indicator	Regions			
		Lviv n=20	Ternopil n=20	Ivano-Frankivsk n=20	Volyn n=20
GPL, Un. E 480/ ml	Lim M±m	1,25–2,35 1,71±0,059	1,32–1,95 1,69±0,042	1,36–1,88 1,61±0,038	1,35–1,98 1,65±0,039
DC, µmol/l	Lim M±m	8,78–13,63 10,87±0,291	9,53–14,45 11,04±0,288	8,46–12,64 10,11±0,287	8,53–13,12 10,38±0,319
MDA, µmol/l	Lim M±m	4,13–9,38 6,9±0,39	4,56–10,12 7,1±0,40	4,24–9,38 6,5±0,36	4,56–10,38 6,7±0,35
SOD, % block. react/1 g Hb	Lim M±m	0,265–0,395 0,332±0,009	0,271–0,416 0,343±0,011	0,245–0,395 0,337±0,010	0,285–0,412 0,351±0,008
GPO, µmol/ min GSH for 1g Hb	Lim M±m	245,0–405,0 327,1±10,52	275,0–424,0 346,2±10,06	281,0–386,0 333,7±8,28	289,0–405,0 348,04±8,24

The POL indicators we obtained in the body of dry-feeding cows in the investigated farms of the western region of Ukraine coincide with the results of O.V. Slypanyuk with co-authors, who claim that increased POL processes have a negative effect on the physiological state of deep-bodied cows[53]. Indicators of MDA concentration are significantly different from those given in clinically healthy cows L.H. Ulko[54], who notes that their

[53] Слипанюк О.В. Антоняк Г.Л., Сологуб Л.І. Перекисне окиснення ліпідів і антиоксидантний статус у крові корів у останній місяць тільності. *Біологія тварин.* 2000. № 2 (2). С. 83–86.

[54] Улько Л.Г. Антиоксидантний статус корів при кетозі. *Вісник Сум. нац. аграр. ун-ту.* 2004. № 7 (12). С. 151–153.

MDA content was on average 2.24±0.19 µmol/l.; n patients with ketosis, it was 5.96±0.24 and even 7.54±0, 63 µmol/l. Therefore, in cows suffering from anemia, POL processes increase, and their level is similar to indicators for ketosis.

The antioxidant protection system protects the animal body from AFO and its metabolism of toxic products, which includes three levels. The first level is responsible for preventing the formation of free radicals. It consists of three fractions: SOD, GSH, and catalase. Thus, the activity of SOD in the erythrocytes of sick cows in the farms of the studied regions ranged from 0.245 to 0.416 % block–react/1 g of Hb. We did not establish a potential difference in the activity of SOD in cows from different regions: the lowest average indicator was found in cows from the Lviv region, the highest in the Volyn region (0.332±0.009 and 0.351±0.008 % block. react/1 g of N). The activity of GPO of erythrocytes is the highest (348.04 µmol/min. GSH per 1 g of Hb) in cows of the Volyn region. However, the difference in the average value of GPO activity between the groups of cows in the areas studied was implausible because there were both hematologically healthy and anemic cows. Therefore, we compared the indicators of POL and ADS in cows of these two groups (Table 11).

Table 11

Indicators of POL and ADS in cows with nutritional deficiency anemia

№	Indicator	Unit of measurement	Hematologically healthy	Patients with anemia	p<
1	GPL	Un. E 480/ml	1,25–1,58 1,45±0,096	1,58–2,35 1,84±0,034	0,001
2	DC	µmol/l	8,46–10,46 9,23±0,57	9,69–14,45 11,80±0,23	0,001
3	MDA	nmol/l	4,13–6,12 4,97±0,12	5,97–10,38 8,25±0,24	0,001
4	SOD	%block react./1^2 Hb	0,245–0,347 0,29±0,0044	0,32–0,42 0,38±0,0044	0,001
5	GPO	µmol/min GSH for 1 gr Hb	245–337 289±4,40	327–424 377±4,80	0,001

As can be seen from the results presented in Table 9, the number of POL products in the blood increases, especially DC and MDA (by 20.2 and 66.0%, respectively).

To restore the disturbed balance in cows with nutritional deficiency anemia, the activity of ADS enzymes increases: SOD and GPO – by 1.3 times ($p<0.001$). We established a direct correlation dependence of a medium degree between SOD and GPL ($r = 0.6659$), a high degree – between SOD activity and the concentration of DC and MDA ($r = 0.828$ and 0.875, respectively), as well as GPO and GPL ($r = 0.696$), GPO and DC and MDA ($r = 0.855$ and 0.837, respectively).

Calculations of the correlation coefficient confirm that the ADS mechanism functions are sufficiently high in nutritional deficiency anemia.

Therefore, both the intensity of peroxide processes and the activity of the antioxidant defense system increase in the body of cows suffering from nutritional deficiency anemia.

CONCLUSIONS

After conducting studies in Lviv, Ternopil, Ivano-Frankivsk, Volyn, Rivne and Chernivtsi regions, anemia was diagnosed in 84 from 160 (52.5 %) cows, moreover, the combination of oligochromemia and oligocythemia was found in 57 cows (35.6 %), only oligochromemia – in 25 (15.6 %), oligocytemia – in 2 (3 %).

The main cause of nutritional-deficiency anemia in cows from the above areas were insufficient supply of raw and digestible protein, cobalt and cuprum (34.5–45.4 and 65,5–82.2 % respectively), low concentration of trace elements in 1 kg of dry matter of the diet (respectively 0.19–0.25 and 5.9–7.4 mg).

Hemoglobin content in patients with alimentary-deficiency anemia of cows was in the range of 67.9-94.3 g/l (84.9 ± 0.59), the number of erythrocytes-3.4-5.8 T/l (4.74,7±0,045).

Anemia in most cows is normochromic (84.5 %) and normocytic (92.24 %), less often – hyper- (9.5 %) or hypochromic (6 %) and macrocytic (4.76 %).

In the blood of cows with alimentary-deficiency anemia, low content of Cobalt (0.18–0.61 μmol/l), Cuprum (8.19–19–15.19 μmol/l) and cyanocobalamin (154–386 ng/l) were established; for norms 0,50-0,85; 12.6–18.9 μmol/l and 300–600 ng/l.

A direct correlative relationship has been established between the content of cyanocobalamin and cobalt ($r=+0.67$).

Nutritional-deficiency anemia is accompanied by increased of lipid peroxidation (LPO): the content of diene conjugates (DC), lipid hydroperoxides (LHP) and malonic dialdehyde (MDA) increases in the blood and increases the activity of antioxidant protection enzymes – superoxide-dysmutase (SOD) and glutathione peroxidase (GPO).

A direct correlative relationship has been established between SOD activity and LHP content ($r = 0.6659$), SOD and DC and MDA ($r = 0.828$ and 0.875, respectively), as well as between GPO and LHP ($r = 0.696$), GPO and DC and MDA ($r = 0.855$ and 0.837).

SUMMARY

The results of the research on the alimentary-deficient anemiae spread in cows, based on the amount of erythrocytopoesis in cows of the western biogeochemical zone of Ukraine; the specific etiological factors, microelemental and B12 vitamin composition of blood; populational structure of erythrocytes; state of POL and AOD are presented in the monograph.

Found that the main reasons for the development of alimentary anemia in dry cows were the low content of Co, Cu and J in the vast majority of rations, their low concentration in 1 kg of dry matter, and hence the insufficient level of their supply to the body. The concentration of cobalt is especially low: 2.5 times less (0.19–0.25 mg/kg) than the minimum (0.55 mg/kg).

The analysis of the results of the fractionation of peripheral blood in the sucrose density gradient shows that the blood of dry cows of all regions consists mostly of populations of "old" and "mature" erythrocytes, the number of "young" is slightly less than half and on average was from 45.3±0.52 to 48.4±0.43%.

In cows suffering from anemia, the share of the population of "mature" erythrocytes increases (+2.4%), which indicates a more intensive maturation of them and their release into the bloodstream ($p<0.001$). At the same time, the share of "young" erythrocytes in them is somewhat lower (by 1.6%; $p<0.01$) than in healthy cows.

Since acid resistance depends on the age of erythrocytes, the dynamics of their acid resistance in farm cows have been studied. The erythrogram of dry cows of the Volyn region was characterized by a pronounced peak of hemolysis at the third minute, which was 15.9%. Haemolysis of erythrocytes was completed in 6.5 minutes, which is faster compared to Ternopil and Lviv regions, respectively, by 1.0 and 1.5 minutes (Fig.1),

since the number of young erythrocytes is more significant in these regions, especially in Lviv region.

Our analysis of the morphological composition of blood and the content of microelements (Fe, Co, and Cu) in 160 cows showed that the low level of cobalt and copper is a problem in the entire Western region of Ukraine.

In anemic cows, the content of both essential trace elements was probably ($p<0.001$) lower: copper by 12.4% and cobalt by 21.1%. In cows suffering from anemia, the level of both MEs is probably lower ($p<0.001$) than in healthy cows (according to the hemoglobin content and the number of erythrocytes).

According to our research, both the intensity of peroxide processes and the activity of the antioxidant defense system increase in the body of cows suffering from nutritional deficiency anemia.

Bibliography

1. Сукманський О.І., Улизько С.І. Визначення поняття і класифікація анемій. *Вісник Білоцерків. держ. аграр. ун-ту.* 2000. № 13 (2). С. 161–164.

2. Левченко В.І., Слівінська Л.Г. Поширення аліментарно-дефіцитної анемії у корів у Західних областях України. *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2010. Т. 12, № 3 (1). С. 190–196.

3. Слівінська Л.Г., Щербатий А.Р. Діагностика мікроелементозів кобил у західній біогеохімічній зоні України. *Вет. медицина України.* 2013. № 4 (206). С. 25–28.

4. Влізло В.В., Сологуб Л.І., Янович В.Г., Антоняк Г.Л., Янович Д.О. Біохімічні основи нормування мінерального живлення великої рогатої худоби. 2. Мікроелементи. *Біологія тварин.* 2006. № 8 (1–2). С. 41–62.

5. Слівінська, Л.Г., Демидюк С.К., Щербатий А.Р. Синдроматика та стан метаболічних процесів у корів за мікроелементозів. *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2017. Т. 19. № 78. С. 182–186.

6. Левченко В.І., Слівінська Л.Г. Поширення аліментарно-дефіцитної анемії у корів у Західних областях України. *Науковий вісник Львівського національного університету ветеринарної*

медицини та біотехнологій імені С. З. Гжицького. 2010. Т.12. № 3 (45). С. 190–196.

7. Hejna M., Gottardo D., Baldi A., Dell'Orto V., Cheli F., Zaninelli M., Rossi L. Review: Nutritional Ecology of Heavy Metals. *Animal.* 2018. Vol. 12. P. 2156–2170.

8. Goff J.P. Invited Review: Mineral Absorption Mechanisms, Mineral Interactions That Affect Acid–Base and Antioxidant Status, and Diet Considerations to Improve Mineral Status. *J. Dairy Sci.* 2018. Vol. 101. P. 2763–2813.

9. Слівінська Л.Г. Еритроцитопоез та обмін заліза у тільних корів. *Вісник Білоцерків. держ. аграр. ун-ту.* 2006. № 40. С. 182–188.

10. Spears J.W. Kegley E.B., Mullis Z.A. Bioavailability of coopfer from tribasic copper chloride and coopfer sulfate in growing cattle. *Anim. Feed Sci. Technol.* 2004. Vol. 116 (1–2). P. 1–13.

11. El-Sisy, G. A., A. M. A. Abdel-Razek, A. A. Younis, A. M. Ghallab, and M. S. S. Abdou. Effect of dietary zinc or Selenium supplementation on some reproductive hormone levels in male Baladi Goats. *Global Vet.* 2008. Vol. 2 (2). P. 46–50.

12. Левченко В.І., Слівінська Л.Г. Поширення аліментарно-дефіцитної анемії у корів у Західних областях України. *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2010. Т. 12. № 3 (45). С. 190–196.

13. Слівінська Л.Г. Еритроцитопоез та обмін заліза у тільних корів. *Вісник Білоцерків. держ. аграр. ун-ту.* 2006. № 40. С. 182–188.

14. Левченко В.І., Безух В.М., Сахнюк В.В. Доклінічний перебіг метаболічних хвороб. *Вісник Білоцерків. держ. аграр. ун-ту.* 2001. № 16. С. 115–120.

15. Слівінська Л.Г. Еритроцитопоез та обмін заліза у тільних корів. *Вісник Білоцерків. держ. аграр. ун-ту.* 2006. № 40. С. 182–188.

16. Слівінська Л.Г. Еритроцитопоез та обмін заліза у тільних корів. *Вісник Білоцерків. держ. аграр. ун-ту.* 2006. № 40. С. 182–188.

17. Судаков М., Береза В., Погурський І. Гіпокобальтоз: діагностика і профілактика в біогеохімічних провінціях України. *Вет. медицина України.* 2000. № 8. С. 6–37.

18. Shcherbatyy, A., Slivinska, L., & Lukashchuk, B. Hypocobaltosis and hypocuprosis in pregnant mares in the western biogeochemical zone of Ukraine (distribution, diagnosis). *Ukrainian Journal of Veterinary and Agricultural Sciences.* 2018. Vol. 1 (2). C. 11-14.

19. Слівінська Л.Г. Поживність кормів та мінеральний склад раціону тільних корів ПСП “Мамаївське” Чернівецької області. *Сільський господар.* 2006. № 11–12. С. 34–36.

20. Слівінська Л.Г. Еритроцитопоез та обмін заліза у тільних корів. *Вісник Білоцерків. держ. аграр. ун-ту.* 2006. № 40. С. 182–188.

21. Левченко В.І., Слівінська Л.Г. Поширення аліментарно-дефіцитної анемії у корів у Західних областях України. *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2010. Т. 12. № 3 (45). С. 190–196.

22. House W.F. Bell A.W. Mineral accretion in the fetus and adnexa during late gestation in Holstein Cows. *J. Dairy Sci.* 2001. Vol. 84 (1). P. 225–232.

23. Лизогуб М., Кондрахін І. Зв’язок вмісту міді та цинку в ланцюгу: грунт-корми-тварина. *Вет. медицина України.* 1997. № 5. С. 24.

24. House W.F. Bell A.W. Mineral accretion in the fetus and adnexa during late gestation in Holstein Cows. *J. Dairy Sci.* 2001. Vol. 84 (1). P. 225–232.

25. Pernes G., Michelle C.F., Lancaster I.G., Murphy J.A. Fat for fuel: lipid metabolism in haematopoiesis. *Clin. Transl. Immunology.* 2019. Vol. 8 (12). P. 1098.

26. Xia Q., Zhang Y., Li Z. Red blood cell membrane-camouflaged nanoparticles: a novel drug delivery system for antitumor application. *Acta Pharm Sin B.* 2019. Vol. 9. P. 675–89.

27. Левченко В.І., Сахнюк В.В., Москаленко В.П. Популяційний склад і властивості еритроцитів у високопродуктивних корів. *Вісник аграрної науки.* 2004. № 10. С. 41–44.

28. Слівінська Л.Г. Структурно-функціональні властивості еритроцитів за анемії різної етіології. *Вісник Білоцерків. нац. ун-ту.* 2009. № 62. С. 81−87.

29. Paiano R.B., Birgel D.B., Birgel Junior E.H. Influence of peripartum on the erythrogram of Holstein dairy cows. *J. S. Afr.Vet. Assoc.* 2020. Vol. 91. P. 1975.

30. Köhne I. Haemolysis induced by mechanical circulatory support devices: unsolved problems. *Perfusion.* 2020. Vol. 35 (6). P. 474-483.

31. Слівінська Л.Г. Поживність кормів та мінеральний склад раціону тільних корів ПСП “Мамаївське” Чернівецької області. *Сільський господар.* 2006. № 11–12. С. 34–36.

32. Jaskowski J. Desorpcja jonow miedzi w zroznicowanych warunkach glebowych. *Mikcroelementy w rolnictwie.* 2002. Vol. 1. P. 83–88.

33. Sharma M.C., Joshi C., Pathak N.N., Kaur H. Copper status and enzyme, hormone, vitamin and immune function in heifers. *Res. Vet. Sci.* 2005. Vol. 79 (2). P. 113–123.

34. Сологуб Л.І., Антоняк Г.Л., Стефанишин О.М. Роль міді в організмі тварин. *Біологія тварин.* 2004. Т. 6. № 1–2. С. 64–76.

35. Alagawany M., Elnesr S.S., Farag M.R., Tiwari R., Yatoo M.I., Karthik K., Michalak I., Dhama K. Nutritional significance of amino acids, vitamins and minerals as nutraceuticals in poultry production and health – a comprehensive review. *Vet Q.* 2020. Vol. 41 (1). P. 1–29.

36. Влізло В.В., Сологуб Л.І., Янович В.Г., Антоняк Г.Л., Янович Д.О. Біохімічні основи нормування мінерального живлення великої рогатої худоби. 2. Мікроелементи. *Біологія тварин.* 2006. Т. 8. №. 1–2. С. 41–62.

37. Судаков М., Береза В., Погурський І. Гіпокобальтоз: діагностика і профілактика в біогеохімічних провінціях України. *Вет. медицина України.* 2000. № 8. С. 36–37.

38. Infante M., Leoni M., Caprio M., Fabbri A. Long-term metformin therapy and vitamin B_{12} deficiency: An association to bear in mind. *World J Diabetes.* 2021. Vol. 12 (7). P. 916-931.

39. González-Montaña J.R., Escalera-Valente F., Alonso A.J., Lomillos J.M., Robles R., Alonso M.E. Relationship between Vitamin B_{12} and Cobalt Metabolism in Domestic Ruminant. *An Update. Animals (Basel).* 2020. Vol. 10 (10), P. 1855.

40. Влізло В.В., Сологуб Л.І., Янович В.Г., Антоняк Г.Л., Янович Д.О. Біохімічні основи нормування мінерального живлення великої рогатої худоби. 2. Мікроелементи. *Біологія тварин.* 2006. Т. 8. № 1–2. С. 41–62.

41. Паска М.З., Личук М.Г. Фізіолого-біохімічні критерії обміну кобальту та вітаміну В12 у телят. *Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Гжицького.* 2009. Т. 11. № 3-2 (42). С. 123–126.

42. Паска М.З., Личук М.Г. Метаболічні реакції організму бугайців поліської м’ясної породи залежно від типів вищої нервової діяльності при згодовуванні кормової добавки «Мікроліповіт». *Науковий вісник Львівського національного університету*

ветеринарної медицини та біотехнологій імені С. З. Гжицького. 2014. Т. 16. № 2 (59). С. 271–277.

43. Влізло В.В., Сологуб Л.І., Янович В.Г., Антоняк Г.Л., Янович Д.О. Біохімічні основи нормування мінерального живлення великої рогатої худоби. 2. Мікроелементи. *Біологія тварин.* 2006. Т. 8. № 1–2. С. 41–62.

44. Shcherbatyy, A.R., Slivinska, L.G., Gutyj, B.V., Fedorovych, V.L., Lukashchuk, B.O. Influence of Marmix premix on the state of lipid peroxidation and indices of non-specific resistance of the organism of pregnant mares with microelementosis. *Regulatory Mechanisms in Biosystems.* 2019. Vol. 10. Iss. 1. P.87–91.

45. Gutyj, B., Stybel, V., Darmohray, L., Lavryshyn, Y., Turko, I., Hachak, Y., Shcherbatyy, A., Bushueva, I., Parchenko, V., Kaplaushenko, A., Krushelnytska, O. Prooxidant-antioxidant balance in the organism of bulls (young cattle) after using cadmium load. *Ukrainian journal of Ecology*. 2017. Vol. 7 (4). P. 589-596.

46. Влізло В.В., Сологуб Л.І., Янович В.Г., Антоняк Г.Л., Янович Д.О. Біохімічні основи нормування мінерального живлення великої рогатої худоби. 2. Мікроелементи. *Біологія тварин.* 2006. Т. 8. № 1–2. С. 41–62.

47. Rahdar A., Hasanein P., Bilal M., Beyzaei H., Kyzas G.Z. Quercetin-loaded F127 nanomicelles: Antioxidant activity and protection against renal injury induced by gentamicin in rats. *Life Sci.* 2021. Vol. 276. P. 119420.

48. Слипанюк О.В. Антоняк Г.Л., Сологуб Л.І. Перекисне окиснення ліпідів і антиоксидантний статус у крові корів у останній місяць тільності. *Біологія тварин.* 2000. № 2(2). С. 83–86.

49. Зінко Г.О. Пероксидно-окисні процеси та стан системи антиоксидантного захисту у телят за гастроентериту. *Аграрний вісник Причорномор'я.* 2017. № 83. С. 86–90.

50. Gutyj B., Stybel V., Darmohray L., Lavryshyn Y., Turko I., Hachak Y., Shcherbatyy A., Bushueva I., Parchenko V., Kaplaushenko A., Krushelnytska O. Prooxidant-antioxidant balance in the organism of bulls (young cattle) after using cadmium load. *Ukrainian journal of Ecology.* 2017. Vol. 7 (4). P. 589–596.

51. Shcherbatyy A.R., Slivinska L.G., Gutyj B.V., Fedorovych V.L., Lukashchuk, B.O. Influence of Marmix premix on the state of lipid peroxidation and indices of non-specific resistance of the organism of pregnant mares with microelementosis. *Regulatory Mechanisms in Biosystems.* 2019. Vol. 10 (1). P. 87–91.

52. Slivinska L. G., Shcherbatyy A. R., Lukashchuk B. O. & Gutyj, B. V. The state of antioxidant protection system in cows under the influence of heavy metals. *Regulatory Mechanisms in Biosystems.* 2020. Vol. 11 (2). P. 237–242.

53. Слипанюк О.В. Антоняк Г.Л., Сологуб Л.І. Перекисне окиснення ліпідів і антиоксидантний статус у крові корів у останній місяць тільності. *Біологія тварин.* 2000. № 2 (2). С. 83–86.

54. Улько Л.Г. Антиоксидантний статус корів при кетозі. *Вісник Сум. нац. аграр. ун-ту.* 2004. № 7 (12). С. 151–153.

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