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VARIABILITY IN MACROELEMENTS CONTENT IN BLOOD SERUM OF COWS ACCORDING TO THEIR PHYSIOLOGICAL STATUS AND GROWING CONDITIONS

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Abstract. The work was undertaken to evaluate an influence of the physiological status of (lactating and dried-off) cows and growing conditions (farm) on the variability of selected macroelements in cow blood serum. The evaluation was done using random models (models of variance components) as well as the classical variability coefficient. It has been found that the cow physiological condition influences the concentration and variability of examined elements. Sampling dates to a greater extent modified the content of investigated macroelements compared to the farms. There has also been found a significant share of an interaction of these factors and random effects (the experimental error) in the variability of examined elements.

Key words: blood serum, cows, macroelements, variability coefficient, variance components

INTRODUCTION

The content of macroelements in plants, conditioned by e.g. soil fertility, is one of the reasons of the variability of their content in the animal body (more often deficiency rather than excess). Sensitivity to deficiencies or incorrect proportions between feed ingredients changes according to age, health, sex, growing conditions and individual animal characteristics. High-yielding cows are particularly sensitive to mineral deficiency due to their faster metabolism rate and substantial depletion of minerals during an intense lactation [Saba et al. 1996, Berry et al. 2001, Larsen et al. 2001, Yokus and Cakir 2006, Pallesen et al. 2008].

Polish works investigating mineral relations in ruminants have contributed to the knowledge of the interaction of minerals in the soil – plant – animal food chain. While carrying out live tests, the level of minerals is analyzed mainly in blood serum [Kruczyńska and Mocek 1992, Bombik et al. 2002].

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The objective of this paper has been to estimate an impact of cow physiological status (lactating and dried-off cows) and growing conditions (farms) on the variability in the content of selected macroelements in blood serum.

MATERIAL AND METHODS

Research included five dairy farms situated in the Zulawy region. The farms were stocked with three to seven year old cows of Polish HF breed. Their average milk yield was 6000 kg and the milk contained 3.4% fat. The conventional housing system with access to pasture was used. The cows were kept in tiestall barns and fed locally-produced feedstuffs. Daily rations were balanced with respect to protein and energy [Inst. Zootech. 1998].

Twelve animals were selected from each farm, that is six cows at a similar lactation stage, and six cows at their initial dried-off period which, following calving, began the lactation period. Blood samples for examination were collected from an external jugular vein. Sampling was carried out fivefold and always in the morning (before feeding and watering of animals). Samples were collected from two groups of cows: lactating cows and dried-off cows. There were five blood sampling dates for lactating cows: the 3rd, 6th, 9th, 12th and 15th week of lactation. The blood serum of dried-off cows was sampled at five dates, too: in the 2nd week of dried-off period, two weeks prior to calving, and in the 3rd, 6th and 9th week of lactation. A blood serum quantitative analysis of the following macroelements was done: calcium, phosphorus, magnesium, sodium and potassium. The determination was carried out by atomic absorption spectrometry (AAS) using the Unicom 939 device. The inorganic phosphorus level was determined following the Fiske-Subarrow method.

The results were statistically analysed by an analysis of variance according to the linear hypothesis of two-factor cross classification with more than one observation within the sub-group [Trętowski and Wójcik 1991]:

$$y_{ijl} = m + a_i + b_j + ab_{ij} + e_{ijl},$$

in which:

y_{ijl} – value of the examined characteristic for i^{th} sampling date, j^{th} farm and l^{th} animal (cow);
m – population mean;
a_i – effect of i^{th} sampling date;
b_j – effect of j^{th} farm;
ab_{ij} – effect of an interaction of i^{th} sampling date and j^{th} farm;
e_{ijl} – random effect (error effect).

Reciprocal relations (percentage structure) of variance components estimates were the basis of an analysis of an impact of sampling dates, farms, sapling dates × farms interaction and random effects on the variability of macroelements content [Oktaba 1980]). The models, whose estimators are the highest reliability estimates, are worked out when the factors investigated are populative in character and their levels constitute a random sample from this population [Rao 1972, Lamotte 1973].

The variance analysis scheme for this model (according to the previously assumed linear hypothesis) is presented in Table 1.

Table 1. Scheme of variance analysis for a random model of two-factor cross classification with more than one observation within the sub-group
Tabela 1. Schemat analizy wariancji dla modelu losowego 2-czynnikowej klasyfikacji krzyżowej z większą niż jedna obserwacja w podgrupie

Sources of variation Źródła zmienności	Degrees of freedom Stopnie swobody	Expected values of mean squares Wartości oczekiwane średnich kwadratów
Sampling dates – Terminy pobrań	a–1	$\sigma_e^2 + n\sigma_{ab}^2 + bn\sigma_a^2$
Farms – Fermy	b–1	$\sigma_e^2 + n\sigma_{ab}^2 + bn\sigma_a^2$
Sampling dates x farms Terminy pobrań x fermy	(a–1) (b–1)	$\sigma_e^2 + n\sigma_{ab}^2$
Error – Błąd	ab (n–1)	σ_e^2

a – number of sampling dates – liczba terminów pobrań (a = 5);
b – number of farms – liczba ferm (b = 5);
n – number of cows in a group – liczba krów w grupie (n = 6);
σ_a^2, σ_b^2, σ_e^2, σ_{ab}^2– respective variance components – odpowiednie komponenty wariancyjne.

Additionally, variability estimation for examined macroelements in the cow blood serum was done by means of the variability coefficient defined as the standard deviation expressed as a percentage of the arithmetic mean [Ruszczyc 1978]. Genetic and environmental factors constitute the basis of the variability among animals which is translated into the variability coefficient. The variability can be smaller or larger depending on kind of experimental material is being tested (more or less homogenous). However, the variability is always present and constitutes the experimental error [Bombik et al. 2004].

RESULTS AND DISCUSSION

Statistical description of the variability of the macroelements content in the blood serum of lactating and dried-off cows is presented in Table 2 and 3, respectively.

An average content of all the examined macroelements was higher in dried-off rather than lactating cows. In the case of the lactating cows, the variability range for the sampling dates was broader for the calcium, sodium and potassium contents whereas the variability of phosphorus and magnesium contents were higher for the farms. In the case of dried-off cows the larger variability range for the sampling dates was found for the magnesium and potassium contents whilst the phosphorus content variability was higher for the farms. The variability of calcium, sodium and potassium contents was similar for both the farms and sampling dates.

The highest variability translated into the variability coefficient value, was recorded for phosphorus and magnesium in lactating cows (38.1 and 28.2%, respectively) and dried-off cows (21.1 and 22.1%, respectively). For both cow groups the lowest variability was

found for the sodium content (2.4 and 2.7%, respectively). The variability of the content of all the elements (apart from calcium) was higher in lactating rather than dried-off cows.

Table 4 illustrates the variability structure of the content of macroelements in the blood serum of cows according to their physiological status and growing conditions.

Table 2. Statistical description of the variability of the content of macroelements (mmol · dm^{-3}) in the blood serum of lactating cows

Tabela 2. Charakterystyka statystyczna zmienności zawartości makroelemntów (mmol · dm^{-3}) w surowicy krwi krów w laktacji

Macroelements Makroelementy	Arithmetic mean Średnia arytmetyczna	Variability range Zakres zmienności		Variability coefficient, % Współczynnik zmienności, %
		for sampling dates dla terminów pobrań	for farms dla ferm	
Calcium, Ca Wapń, Ca	2.39	2.28–2.52	2.34–2.46	10.3
Phosphorus, P Fosfor, P	0.712	0.700–0.740	0.640–0.840	38.1
Magnesium, Mg Magnez, Mg	0.720	0.680–0.760	0.660–0.800	28.2
Sodium, Na Sód, Na	140	138–141	139–140	2.4
Potassium, K Potas, K	4.99	4.61–5.26	4.80–5.10	7.8

Table 3. Statistical description of the variability of the content of macroelements (mmol · dm^{-3}) in the blood serum of dried-off cows

Tabela 3. Charakterystyka statystyczna zmienności zawartości makroelementów (mmol · dm^{-3}) w surowicy krwi krów zasuszonych

Macroelements Makroelementy	Arithmetic mean Średnia arytmetyczna	Variability range Zakres zmienności		Variability coefficient, % Współczynnik zmienności, %
		for sampling dates dla terminów pobrań	for farms dla ferm	
Calcium, Ca Wapń, Ca	2.50	2.46–2.56	2.44–2.56	12.6
Phosphorus, P Fosfor, P	1.024	0.980–1.100	0.860–1.080	21.1
Magnesium, Mg Magnez, Mg	0.940	0.760–1.100	0.860–1.040	22.1
Sodium, Na Sód, Na	141	140–142	140–143	2.7
Potassium, K Potas, K	5.16	5.04–5.26	5.06–5.26	5.2

Table 4. Variability structure (variance components in %) of the content of macroelements in the blood serum of cows according to their physiological status and growing conditions

Tabela 4. Struktura zmienności (komponenty wariancyjne w %) zawartości makroelementów w surowicy krwi krów w zależności od ich stanu fizjologicznego i warunków utrzymania

Physiological status of cows Stan fizjologiczny krów	Sources of variability Źródła zmienności	Macroelements Makroelementy				
		Ca	P	Mg	Na	K
Lactating cows Krowy w laktacji	sampling dates termin pobrania	13.0	0	0	0	19.5
	farms – fermy	0.5	4.6	4.0	0	0
	sampling dates x farms termin pobrania x fermy	0	2.7	0	30.6	26.3
	error – błąd	86.5	92.7	96.0	69.4	54.2
Dried-off cows Krowy zasuszone	sampling dates termin pobrania	0	0	3.4	1.0	0
	farms – fermy	0	3.7	0	6.6	0
	sampling dates x farms termin pobrania x fermy	0.3	30.3	53.1	0	51.8
	error – błąd	99.7	66.0	43.5	92.4	48.2
Ratio of total variability of cows lactating and dried-off Stosunek całkowitej zmienności u krów w laktacji i zasuszonych		41 : 59	53 : 47	30 : 70	51 : 49	65 : 35

For lactating cows, the blood sampling dates most markedly determined the potassium and calcium contents (19.5 and 13.0% total variability, respectively) whereas for dried-off cows this factor slightly influenced the magnesium and sodium contents (3.4 and 1.0%, respectively).

Farms slightly modified the contents of studied macroelements in lactating cows: phosphorus content in 4.6% total variability, magnesium content in 4.0%, and calcium content in 0.5%, and in dried-off cows: sodium content in 6.6% and phosphorus content in 3.7% total variability.

The sampling dates × farms interaction modified the content of sodium (30.6% total variability), potassium (26.3%) and phosphorus (2.7%) in lactating cows, and the content of magnesium (53.1%), potassium (51.8%), phosphorus (30.3%) and calcium (0.3%) in dried-off cows.

The variability of the content of the analysed macroelements was substantially influenced by random effects (error). In lactating and dried-off cows random effects modified the content of magnesium in 96.0 and 43.5%, phosphorus in 92.7 and 66.0%, calcium in 86.5 and 99.7%, sodium in 69.4 and 92.4% and potassium in 54.2 and 48.2% total variability, respectively.

Among the macroelements investigated, the total variability of sodium content was almost the same in both lactating and dried-off cows (variability ratio 51 : 49), whereas for potassium and calcium contents it was similar (the respective ratios were: 53 : 47 and 41 : 59). The potassium content variability was markedly higher in lactating cows compared to dried-off cows (ratio 65 : 35) whereas in the case of the magnesium content the relation was reversed (ratio 30 : 70).

To sum up, it should be noted that the content of macroelements in cow blood serum depended on their physiological status, higher levels of investigated elements being determined for dried-off cows compared to the lactating cows. Similar relationships in high-yielding animals were found by other authors [Lachowski and Wojciechowski 1992, Horst et al. 1997, Larsen et al. 2001, Kupczyński and Chudoba-Drozdowska 2002, Yokus and Cakir 2006].

An substantial influence of sampling dates on the variability of calcium and potassium levels could result from different capabilities of individual animals connected with faster or slower rate of cows entering successive lactation weeks.

A small influence of farms on phosphorus, magnesium and calcium contents in lactating cows and sodium and phosphorus contents in dried-off cows could be connected with differences in the elements' contents in feedingstuffs applied on individual farms [Czuba 1994, Kwiatkowski et al. 1989, Bombik et al. 2002, Pallesen et al. 2008]. A marked share of an interaction of sampling dates and farms in the variability of the examined macroelements supports the above inference.

CONCLUSIONS

1. The estimation of cow body supply with selected minerals showed that its physiological status influenced the concentrations of the examined minerals. The blood serum of dried-off cows had a higher level of the analysed minerals than that of lactating cows.

2. Among the analysed factors sampling dates exerted more influence on the variability of the examined macroelements than farms. Also the share of sampling dates × farms interaction in the variability of the above-mentioned macroelements was substantial, which indicates that the response of animals to growing conditions, feeding in particular, was different.

3. Error effects, associated with individual variability of animals within experimental groups and the presence of genetic and environmental conditions of mineral metabolism, substantially modified the variability of examined macroelements.

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ZMIENNOŚĆ ZAWARTOŚCI MAKROELEMENTÓW W SUROWICY KRWI KRÓW W ZALEŻNOŚCI OD ICH STANU FIZJOLOGICZNEGO I WARUNKÓW UTRZYMANIA

Streszczenie. W pracy dokonano oceny wpływu stanu fizjologicznego krów (w laktacji i zasuszonych) oraz warunków utrzymania (ferm) na zmienność wybranych makroelementów w surowicy krwi krów. Oceny tej dokonano korzystając z modeli losowych (modeli komponentów wariancyjnych) oraz klasycznego współczynnika zmienności. Wykazano, że stan fizjologiczny krów ma wpływ na stężenie i zmienność badanych pierwiastków. Terminy pobrań w większym stopniu modyfikowały zawartość badanych makroelementów w porównaniu z fermami. Znaczący jest także udział interakcji tych czynników i efektów losowych (błędu doświadczalnego) w zmienności badanych pierwiastków.

Słowa kluczowe: komponenty wariancyjne, krowy, makroelementy, surowica krwi, współczynnik zmienności

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