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The effect of supplementing rations with selenium and vitamin E on biochemical parameters in blood and performance of cows in the early stage of lactation

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ABSTRACT

Thirty-two cows (Black-and-White x HF) in the first 100 days of lactation were divided into 4 groups and fed rations composed of equal proportions of roughages and concentrates in amount of 1 kg per 2 kg of milk at yield exceeding 12 kg/day. The concentrates were supplemented with vitamin E (group I, 336 mg; groups II, III, and IV, 672 mg/cow/day) and selenium: group I, no supplementation; group II, 4 mg/cow/day as sodium selenite; group III, 4 mg/cow/day as selenium yeast; group IV, 2 mg/cow/day as selenium yeast.

Cows fed selenium-supplemented rations had significantly elevated serum selenium concentrations (group I, 0.0214 mcg/ml; II- 0.0453 mcg/ml; III, 0.0654 mcg/ml; IV, 0.0573 mcg/ml). Selenium from yeast was utilized better than sodium selenite. Regardless of the source of selenium, Se lowered serum a-tocopherol (0.245 vs 0.229; 0.187; 0,232 mg/dl) and retinol (35.57 vs 31.46; 32.25; 29.29 mcg/dl) levels. The addition of selenium when the vitamin E content of the ration was increased modified the lipid metabolism of cows (elevated HDL and triglycerides).

KEY WORDS: lactating cows, selenium, vitamin E, blood metabolites

INTRODUCTION

Schwarz and Foltz (1957) were the first to show that selenium is an essential element in the diets of mammals. Both a deficit and excess of this element adversely affect many metabolic processes. Selenium plays an important role in antioxidation mechanisms, protecting the body from heavy metal poisoning and ac-

cumulation (MacPherson, 1994). It takes part in processes increasing immunity and exhibits immunostimulatory properties (Ellis et al., 1990). Together with tocopherol, selenium is involved in muscle metabolism. It was found that selenium deficit in cattle and sheep caused nutritional muscle dystrophy (NMD), which exacerbates in the winter and spring (Godwin, 1975). The seasonality of NMD is correlated with the seasonal decline in the vitamin E content of feeds. Selenium also participates in reproductive processes; its defficiency increases the frequency of peripartum complications (Hong et al., 1989). Selenium as an antioxidant also inhibits the transformation of neoplastic cells, decreasing in this way the probability of developing malignancies (Martin and Schillaci, 1984). It also affects pancreatic function, thus plays an important role in the digestion of fats and absorption of lipophilic vitamins (MacPherson, 1994). On a global scale, selenium toxicity is minuscule in comparison with the consequences of its deficit. Some regions of Poland are affected by a selenium deficit (Dębski, 1992; Kleczkowski et al., 1996).

According to NRC Standards (1989) feeds used for ruminants should contain from 0.1 to 0.3 mg selenium/kg DM. Stowe et al. (1988) report that for lactating cows to achieve a normal serum selenium level, they should consume from 5 to 7 mg Se daily.

The availability of selenium from mineral compounds (sodium selenite, sodium selenate) in the gastro-intestinal tract of ruminants is poor. Most of these compounds are reduced by ruminal microflora to unavailable forms that are excreted with faeces, polluting the environment (Grela, 1997). It was found that organic selenium compounds (selenium yeast, selenium-methionine) added to feeds caused a two-fold greater rise in glutathione peroxidase activity in cattle than did selenite (Pherson et al., 1989; Fisher et al., 1995).

Organic selenium compounds should be used in the feeding of ruminants. Selenium yeast is particularly suitable because the yeast cell wall protects selenium from bacterial reduction in the rumen (Coenders, 1995). Thanks to the greater bioavailability of selenium in this yeast, the amount added to feed may be reduced.

The objective of this study was to determine the effect of supplementing rations with sodium selenite, selenium yeast and vitamin E on selected biochemical parameters of blood and on the performance of cows in the early stage of lactation.

MATERIAL AND METHODS

The study was conducted on 32 multiparous crossbred Black-and-White x HF cows (3^{rd}-4^{th} lactation) with body weights of 660 kg (± 20 kg), during the first 100 days of lactation. The cows were assigned by an analogue method to 4 groups, taking into account age, body weight, number of lactation, and milk yield. The

study was carried out in the winter. All of the groups received a uniform ration composed of maize silage (20 kg), grass and sugar beet leaf silage (15 kg), wilted-grass silage (10 kg) and meadow hay (2 kg). The concentrate was fed when daily milk yield exceeded 12 kg FCM, in an amount of 1 kg per 2 kg milk. The concentrate was supplemented with 120 g/cow/day of premix (Polfamix U, Pharmaceutic Plant BASF Kutno, Poland). Group I (control) received the standard Polfamix U formula without selenium. Experimental groups II, III and IV were fed Polfamix U with an increased vitamin E (α-tocopherol acetate) content and inorganic selenium (sodium selenite) or organic selenium as bioplex-Se (selenium yeast).

The experimental design, selenium and vitamin E doses are given in Table 1.

TABLE 1

Scheme of experimenent

Groups	n	Content in Premix		Premix	Vitamin E		Selenium	
		vitamin E g/kg	selenium mg/kg	mg/h/d	mg/h/d	mg/kg DM	mg/h/d	mg/kg DM
I	8	2.8	-	120	336	17.9	-	-
II	8	5.6	33.3[1]	120	672	35.8	4	0.213
III	8	5.6	33.3[2]	120	672	35.8	4	0.213
IV	8	5.6	16.6[2]	120	672	35.8	2	0.106

[1] selenium selenite

[2] selenium yeast (Alltech Inc. Biotechnolgy Center, KY, USA)

Milk yield was monitored every two weeks, and is expressed as milk with standard fat, protein and dry matter contents (kg FCM, kg FPCM, kg SCM). Fat, protein, lactose and dry matter in average samples of milk were determined using a Milco Scan-104 apparatus. The somatic cell count (SSC) was determined with a Fosomatic analyzer.

Blood for determination of selected biochemical parameters was drawn 3 times from the jugular vein on days 30, 60 and 90 of lactation. The following were determined in the serum: glucose by the hexokinase method, total and HDL (high density lipoprotein) cholesterol by the Röschlau et al. (1974) method, triglycerides by the Wahlefeld (1974) method modified by the company, A. Diagnostic Ltd., Warsaw (Poland). The retinol and α-tocopherol contents were determined in serum by HPLC (Cuesta Sanz, Castro Santa-Gruz, 1986). Serum selenium was assayed by atomic mass spectrometry (Clinton, 1977) using a Solar 939 UNICAM spectrometer linked to a continuous hydride-generating UNICAM VP 90 vapour system.

The results of serum assays are presented as averages of three consecutive determinations on days 30, 60 and 90 of lactation.

The results showing the blood parameters, milk yield and milk composition were subjected to statistical analysis using single factorial analysis of variance and the Duncan multiple range test.

RESULTS AND DISCUSSION

The concentrations of selenium in serum, milk and the activity of glutathione peroxidase (GSH-Px) in blood can be used as indicators of the supply of selenium to cows (Pehrson, 1989; Dębski, 1992; Fisher et al., 1995; Kleczkowski et al., 1996; Awadeh et al., 1998). McDowell (1985) and Dębski (1992) state that the serum selenium levels in cows should not fall below 0.03-0.04 mcg/ml. Concentrations below 0.030 mcg/ml are considered to reflect selenium deficiency. Harrison et al. (1984) found that lowering Se concentrations to under 0.050 mcg/ml in cows increased the risk of retaining the placenta.

The average serum concentration of selenium (Table 2) in the control group (I) suggests that the ration did not provide sufficient selenium. The studies conducted by Dębski (1992) and Kleczkowski et al. (1996) revealed selenium deficiency in over 77% of the territory of Poland. Among others, northeastern Poland is considered a region of considerable selenium deficiency (Dębski, 1992).

TABLE 2

Concentrations of selenium in the blood serum of cows, mcg/ml

Item	Groups			
	I	II	III	IV
x	0.0214^{A}	0.0453^{B}	0.0654^{C}	0.0573^{D}
s	0.0027	0.0033	0.0070	0.0049

^{A,B,C,D} $P<0.01$

Supplementing the rations of cows with selenium in the form of sodium selenite (group II) or selenium yeast (groups III and IV) significantly increased serum selenium concentrations (Table 2). The results also point to considerable differences in availability of selenium to cows depending on the source of the element. The serum selenium levels in cows fed 4 mg Se/day as sodium selenite (group II) doubled in comparison with the control group (0.0453 mcg/ml vs 0.0214 mcg/ml), whereas cows receiving 4 mg Se/day (group III) as selenium yeast showed an over 3-fold increase (to 0.0654 mcg/ml) in comparison with group I. These results show that selenium in organic form is more available to ruminants than inorganic selenium compounds. This is borne out by the significantly higher se-

rum selenium concentrations in group IV cows receiving 2 mg Se/day as selenium yeast than in group II cows fed 4 mg selenium/day as sodium selenite (0.0573 mcg/ml vs 0.0453 mcg/ml). These results are also supported by other studies (Pehrson et al., 1989; Coenders, 1995; Fisher et al., 1995). Pehrson et al. (1989) found that in ruminants, the availability of selenium from organic compounds (selenium yeast, selenium-methionine) was twice that of inorganic compounds.

Among factors that can mitigate the effects of selenium deficiency, McDowell et al. (1996) name high doses of vitamin E, since this vitamin and selenium cooperate in many metabolic processes. Increasing the vitamin E content in the ration for cows by 100% (672 mg/cow/day vs 336 mg/cow/day) did not lead to a higher serum a-tocopherol concentration (groups II, III and IV) (Table 3). On the contra-

TABLE 3

Concentrations of a-tocopherol and vitamin A in the blood serum

Indices	Groups			
	I	II	III	IV
α-tocopherol, mg/dl				
x	0.245^{A}	0.229^{A}	0.187^{B}	0.232^{A}
s	0.047	0.036	0.046	0.045
Retinol, mcg/dl				
x	35.57	31.46	32.25	29.29
s	7.50	5.07	6.91	6.77

^{A,B} – $P<0.01$

ry, a declining tendency of serum vitamin E concentrations in these groups was observed. A significant decline in the vitamin E concentration in the serum of cows in group III that received 4 mg Se in the form of selenium yeast was found; these cows had the highest serum selenium concentrations (0.065 mcg/ml).

According to NRC Standards (1989) the requirement for vitamin E in cows is from 15 to 40 mg/kg feed. Nonetheless, in many studies in order to improve the supply of this vitamin to cows, considerably higher doses than those recommended by NRC Standards were used. In the study by Focant et al. (1998), the stability of milk fat was significantly increased and the effects of oxidation were reduced in cows supplemented with 9616 IU of vitamin E (7070 mg α-tocopherol acetate[1]) during lactation. Hidiroglau et al. (1994), however, administered 3000 IU vitamin E (2205 mg α-tocopherol acetate) by injection to cows and did not observe an

[1] 1 mg D-α-tocopheryl acetate = 1.36 IU vitamin E

increase in the serum α-tocopherol acetate level. McDowell et al. (1996), Zust et al. (1996) and Stowe et al. (1998) state that the a-tocopherol acetate content in the serum of cows should be within 2-4 mg/l, while values under 1.5 mg/l point to a deficit of this vitamin.

The serum vitamin E level is usually correlated with the amount supplied in the ration (Smith et al., 1988; Hidiroglou et al., 1994). Weiss et al. (1990) have found that the effect of the vitamin E content of a ration is four times greater in dry cows than in lactating ones. Our results on α-serum tocopherol levels (Table 3) indicate that the addition of selenium affected the metabolism and distribution of vitamin E in the body. It should be noted here that selenium is the second most important trace element next to iodine, that regulates thyroid function, and has a considerable effect on the digestion of fats and absorption of tocopherols in the intestine (Donald et al., 1993).

A reduced serum vitamin A concentration in comparison with the control group (I) was found (Table 3) in cows that received a higher dose of vitamin E plus selenium supplementation (groups II, III and IV). The lowest serum retinol concentration was found in group IV (29.29 mcg/100 ml). The differences in serum retinol concentrations were not statistically significant.

Berger (1989) found that increasing the dose of vitamin E given to chickens increased the vitamin A content in the liver, so it may be supposed that supplementation with selenium and vitamin E led to greater hepatic accumulation of vitamin A, which may have resulted in a lower serum level of this vitamin in the studied cows.

The addition of selenium and vitamin E to rations did not significantly affect glucose levels (Table 4). Serum glucose levels ranged from 2.69 to 3.23 mM/l and were within normal limits.

A significant rise in serum HDL occurred in cows supplemented with 4 mg selenium/day from sodium selenite (group II). Total serum cholesterol levels did not differ significantly among groups (Table 4). Vitamin E and cholesterol are stored and transported in various serum lipoprotein fractions. It had been shown that the LDL (Low Density Lipoprotein) fraction is the main carrier of vitamin E and cholesterol (Kayden and Bjornson, 1972; Lambert and Mourot, 1984), but more recently Herdt and Smith (1996) found that the HDL fraction was the main carrier of vitamin E and cholesterol in the serum of cattle. This fraction was found to contain 77% of the total body contents of vitamin E and 72% of cholesterol. Car et al. (1993) obtained similar results.

Analysis of serum triglycerides (Table 4) showed that supplementation of selenium and vitamin E caused a significant increase in this lipid fraction.

In the selenium-supplemented groups that received a higher vitamin E dose, the daily milk yield increased slightly (kg, FCM, FPCM and SCM; Table 5). This was also reflected in the increased daily yields of the basic components of milk (pro-

TABLE 4

Biochemical indices in blood serum of cows

Groups		Glucose mmol/l	HDL mmol/l	TCH mmol/l	Triglyceride mmol/l
I	x	3.239	0.440^{A}	4.884	0.0496^{Aabc}
	s	0.72	0.03	0.77	0.005
II	x	3.129	0.552^{B}	5.533	0.0535^{Aabcd}
	s	0.34	0.04	0.70	0.006
III	x	3.174	0.452^{A}	4.772	0.0577^{Abab}
	s	0.94	0.09	0.77	0.006
IV	x	2.692	0.458^{A}	5.400	0.0664^{Bbcd}
	s	0.58	0.08	1.13	0.001

^{a,b,c,d} – $P<0.05$; ^{A,B} – <0.01
HDL – high density lipoproteins
TCH – total cholesterol

TABLE 5

Milk production

Yield kg/day		Groups			
		I	II	III	IV
Milk	x	22.4	23.4	23.5	24.3
	s	3.6	2.8	4.3	4.9
FCM	x	22.9	25.3	24.6	25.6
	s	3.9	3.3	4.6	4.9
FPCM	x	22.8	25.0	24.8	25.4
	s	3.7	3.3	4.9	4.8
SCM	x	22.2	24.5	24.1	24.7
	s	3.6	3.3	4.8	4.6
Protein	x	0.669	0.732	0.779	0.755
	s	0.11	0.10	0.19	0.13
Fat	x	0.935	1.061	1.020	1.060
	s	0.17	0.14	0.20	0.20
NFS	x	1.894	2.010	2.029	2.053
	s	0.29	0.26	0.41	0.39

FCM = fat corrected milk (4%)
FPCM = fat protein corrected milk (4%, 3%)
SCM = solids corrected milk
NFS = non fat solids

tein, fat, SMB). In other studies (Angelow et al., 1993) it was shown that a selenium deficit in sheep during lactation caused a fall in milk yield, fat and protein concentrations.

Analysis of the data pertaining to the basic composition of milk (Table 6) shows that milk from cows supplemented with selenium and the larger dose of vitamin E had a higher percentage of protein and fat. No correlation was found, however, between supplementation with selenium and vitamin E and the somatic cell count (SCC).

TABLE 6

Milk composition

Indices		Groups			
		I	II	III	IV
Protein	g/kg	30.7	32.2	33.7	31.8
Fat	g/kg	42.9	46.5	44.5	45.1
Lactose	g/kg	49.2	48.9	47.8	48.3
Density	g/cm^3	1.0298	1.0298	1.0298	1.0298
Dry matter	g/kg	129.9	134.6	133.0	132.3
NFS	g/kg	87.1	88.2	88.6	87.2
SCC	10^3/ml	183.0	170.5	238.8	214.8

SCC – somatic cell counts

CONCLUSIONS

Supplementing rations with selenium, either in inorganic (sodium selenite) or organic (selenium yeast) form, significantly increases the selenium level in the serum of cows. Selenium yeast are a better source of selenium in diets for cows because of the greater availability of this element in comparison with sodium selenite, thanks to which it is possible to reduce the amount added to the ration.

Supplementation of rations with selenium and vitamin E does not significantly affect the milk yield of cows, but tendency towards increased fat and protein contents in milk is observed. But furthermore it affects lipid metabolism.

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STRESZCZENIE

Wpływ dodatku selenu oraz witaminy E do dawki pokarmowej na wskaźniki biochemiczne krwi oraz efekty produkcyjne krów w początkowym okresie laktacji

Trzydzieści dwie krowy (cbxHF) w pierwszych 100 dniach laktacji podzielono na 4 grupy i żywiono dawką złożoną z jednakowej ilości pasz objętościowych i mieszanki treściwej, w ilości 1 kg na 2 kg mleka przy wydajności powyżej 12/kgdzień. Krowy otrzymywały z paszą treściwą dodatek witaminy E (grupa I – 336 mg, grupy II,III i IV – 672 mg/szt./dzień) oraz dodatek selenu: grupa I – bez dodatku, grupa II - 4 mg/szt./dzień w postaci seleninu sodu, grupa III – 4 mg/szt./dzień, grupa IV – 2 mg/szt./dzień w postaci drożdży selenowych.

Wzbogacenie dawki pokarmowej krów w selen wpłynęło istotnie na wzrost zawartości selenu w surowicy krwi (grupa I – 0,0214 mcg/ml, II – 0,0453 mcg/ml, III – 0,0654 mcg/ml, IV – 0,0573 mcg/ml). Selen z drożdży selenowych był lepiej wykorzystywany przez krowy niż z seleninu sodu. Niezależnie od zastosowanego źródła, Se powodował obniżenie zawartości α-tokoferolu (0,245 vs 0,229; 0,187; 0,232 mg/dl) oraz retinolu (35,57 vs 31,46; 32,25; 29,29 mcg/dl) w surowicy krwi. Dodatek selenu przy zwiększonej zawartości witaminy E w dawce dla krów modyfikował gospodarkę lipidową (wzrost HDL i triacylogliceroli).