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Effectiveness of mineral-vitamin supplement to complementary feed mixture for dairy cattle nutrition

Efektywność stosowania dodatku mineralno-witaminowego do mieszanki uzupełniającej w żywieniu krów mlecznych

Summary. The objective of the present study was to evaluate the effect of the commercial complementary feedstuff inclusion into dairy cow nutrition on milk yield and quality. The studies were carried out in a specialized farm for 24 months. The research involved the cows with daily milk production exceeding 20 kg which, having obtained the intended milk yield, were selected successively on the basis of analogues into two treatment groups: control (C) and experimental (E). The experimental factor was a commercial mixture supplement (MS) incorporated into a TMR fed to the E cow group. During the study, the composition, quality and nutritional value of the administered feedstuffs (every 2 months) as well as the yield, composition and quality of cow milk (once a month) were analyzed. The present research indicated a significantly increased milk production efficiency of the cows fed a diet with MS addition of 50 g/day/animal at lactation. The application of the experimental mixture reduced the somatic cell counts (SCC) in milk by ca. 25%. Feed additive inclusion at the amount of 50 g daily per lactating animal is recommended to promote the cow health state, especially the mammary gland, and thus, to improve quality of the obtained milk.

Key words: cow, feeding, mineral-vitamin supplement, yield, milk quality, somatic cell

INTRODUCTION

Dairy cattle rearing and breeding require extensive knowledge, abilities and general care in both, maintenance of good herd breeding practices as well as appropriate choice of feeds, their conservation and processing technology. Besides, proper evaluation of feed nutritional value, especially for high yielding dairy cows is essential. However, the rational cattle nutrition relies not only on a supply of a palatable feed ration of high nutritive value and adequate physical form along with a well balanced energy-protein ratio. It

should also provide organism with a broad range of minerals, vitamins and other dietary additives that are vital to achieve the best efficiency at good health status of animal [Kincaid *et al.* 2003, Enjalbert *et al.* 2006, Nocek *et al.* 2006, Siciliano-Jones *et al.* 2008, Sales *et al.* 2010, Erdman *et al.* 2011]. Feeding a typical total mixed ration (TMR) formulated on basis of maize silage, grass hay silage and concentrate is associated with mineral and vitamin deficiency [Kinal 1999, Erdman *et al.* 2011]. Regarding minerals, deficit of sodium, zinc and copper is reported most commonly [Whitaker *et al.* 1997, Ahola *et al.* 2004, Studziński *et al.* 2006]. Therefore recently, new complementary feeding stuffs have appeared that, if administered at an adequate level, ensure high and sustained cow performance, have the potential to prevent the incidence of metabolic disorders to some extent, minimize herd reproduction problems and contribute to improvement of obtained milk quality [Weiss *et al*. 1990, Oldham *et al.* 1991, Erskine and Bartlett 1993, Bouwstra *et al.* 2010, Lippolis 2011]. The feed additives incorporated into a diet must bring economic benefits and their type and quantity should be tailored to a given farm, regarding cow milk yield and feed ration composition. On that account, it is necessary to perform continuous analysis of herd milk performance in relation to the feed additives applied to monitor both, production quality and profitability [Szulc *et al.* 1992, Jamroz *et al.* 2006]. Notably, a form of the applied mineral components is also critical. The application of microelements in organic complexes prove especially effective [Holwerd *et al.* 1995, Bednarek 1998, Klebaniuk and Grela 2008].

Various dietary supplements to energy-protein balanced feed rations for cows contribute to multi-directional improvement of rearing and breeding performance of these animals. The objective of the research was to assess the effectiveness of employment of a commercial complementary mixture in dairy cattle feeding. Primarily, dietary inclusion of the experimental factor aimed at promoting milk yield, especially the SCC reduction in milk and thus, milk quality improvement.

MATERIAL AND METHODS

The studies were conducted for 24 months (from January 2010 through December 2011) at a farm specialized in dairy cows breeding, i.e. Polish Holstein-Friesian breed, Black-White variety. The cows were under permanent surveillance of the Voivodship Sanitary Inspectorate (VSI) and a local veterinarian as well as underwent the routine screening tests California Mastitis Test (CMT) for bovine mastitis.

The cows in the farm are fed a mono-diet (TMR) throughout the year. The feed rations are formulated according to the true nutritive value of the diets and in compliance with the ruminant feeding program IZ PIB-INRA [2009]. In the analyzed farm, a TMR feeding system adapted several years ago has increased milk performance. There were limited to some extent nutrition-dependent diseases (among others, incidence of acidosis, ketosis, mastitis and reproduction disorders). Currently in the farm, the basic feeds included in a TMR are the following: maize silage, grass hay silage, spent grain, straw and concentrate incorporated at a different dietary ratio, subject to a production group. The key ingredient proportion in a TMR ration intended for the cows under the study is shown below (Tab. 1).

Table 1. Ingredient composition of TMR for experimental cows
Tabela 1. Skład komponentowy TMR dla krów doświadczalnych

Item Wyszczególnienie	Maize silage Kiszonka z kukurydzy	Grass hay silage Siano-kiszonka	Spent grain Młóto	Straw Słoma	Concentrate Mieszanka treściwa	Total Suma
Forage diet kg/d/unit Pasza naturalna kg/dzień/szt.	25	16	6	0.5	7	54.5
% in feed ration Udział w dawce, %	45.9	29.4	11.0	0.9	12.8	100.0

The herd is divided into production groups according to the physiological status and milk production (drying off, periparturient period, milk yield over 20 kg/d, milk yield below 20 kg/d). The studies involved the cows from the production group of the peak milk yield, they were selected successively on the basis of analogues when obtained min. 20 kg/d milk production and allocated to two test groups – control (C) and experimental (E). An experimental factor was a commercial complementary mixture additive (MS) included into a TMR and fed to the cows from the group E (Tab. 2**)** supplied at 50 g/unit/day.

Table 2. Parameters of experimental mixture additive
Tabela 2. Parametry dodatku doświadczalnego

Composition Skład	Component Składnik	Measure (in 1 kg) Jednostka miary (w 1 kg)	Content Zawartość
Macroelements Makroelementy	sodium/sód	g	160
	magnesium/magnez	g	16.2
Microelements Mikroelementy	zinc/cynk	g	8.0
	selenium/selen	g	0.05
	microelements in organic complexes mikroelementy w połączeniach organicznych		+
Vitamine Witaminy	vitamin E/witamina E	g	6.2
	niacin/niacyna	g	40.0
	biotin/biotyna	g	220.0

During the study period, there were recorded mean daily feed intake results, whereas the chemical composition, quality and nutritive value of the feeds provided (TMR) were assessed every 2 months. The milk yield records were taken once a month when milk was collected for the laboratory analyses.

A content of basic nutrients (dry matter, crude protein, crude fiber, ether extract, crude ash) in TMR feed components was determined conforming to the methods standardized by AOAC [2005]. Cow milk production was evaluated with a 1-cylinder WB Auto Sampler milk meter. The milk samples were examined for a level of dry matter, protein, fat and lactose (Bentley 150 milk composition analyzer) and somatic cell counts (Somacount 150).

The studied parameters values were established on the basis of the weighted average calculation. The obtained numerical data underwent the statistical analysis for non-orthogonal data using the Statistica 5.1 software program, while significance of differences was estimated with the Tukey`s test.

RESULTS AND DISCUSSION

Average chemical composition and nutritive value of the feed stuffs supplied during the 2-year experimental period were uniform (Tab. 3) and did not deviate significantly from the data presented in literature [IZ PIB-INRA 2009]. The dietary experimental supplement did not affect markedly the chemical composition or nutritional value of the TMR applied, while feed intake by the cows in the control and experimental group was similar and averaged 18,74 and 18,51 dm/unit/d, respectively.

Table 3. Average chemical composition and nutritive value of feeds
Tabela 3. Średni skład chemiczny i wartość pokarmowa skarmianych pasz

Item Wyszczególnienie	Maize silage Kiszonka z kukurydzy	Haysilage Sianokiszonka	Spent grain Młóto	Straw Słoma	Concen-trate Mieszanka treściwa
Dry matter, g·kg^{-1} Sucha masa, g·kg^{-1}	358	412	242	873	928
In 1 kg DM (g)/W kg suchej masy (g)					
Crude protein Białko surowe	71.4	119.4	337.6	91.1	283.3
Crude fiber Włókno surowe	202.1	358.3	156.2	349.8	49.1
Ether extract Ekstrakt eterowy	37.1	12.4	87.9	17.1	37.5
Crude ash Popiół surowy	52.1	98.7.0	56.3	92.6	83.6
NFE BAW	637.3	509.9	362.0	449.4	546.5
Nutritive value 1 kg DM/Wartość pokarmowa 1 kg suchej masy					
UFL JPM	0.89	0.78	0.93	0.62	1.15
PDIN, g BTJN, g	52	74	227	56	195
PDIE, g BTJE, g	69	69	190	61	175
LFU JWK	1.09	1.23	–	1.18	–

NFE – Nitrogen Free Extract, UFL – Feed Unit for milk production, PDI – Protein truly Digestible in the small Intestine (PDIE – when energy limits microbial protein synthesis, PDIN – when nitrogen limits microbial protein synthesis), LFU – fill units for cows

BAW – związki bezazotowe wyciągowe, JPM – jednostka paszowa produkcji mleka, BTJ – białko trawione w jelicie cienkim (BTJE – białko rzeczywiście trawione w jelicie cienkim, obliczone na podstawie dostępnej w żwaczu energii, BTJN – białko rzeczywiście trawione w jelicie cienkim obliczone na podstawie dostępnego w żwaczu azotu), JWK – jednostka wypełnieniowa dla krów

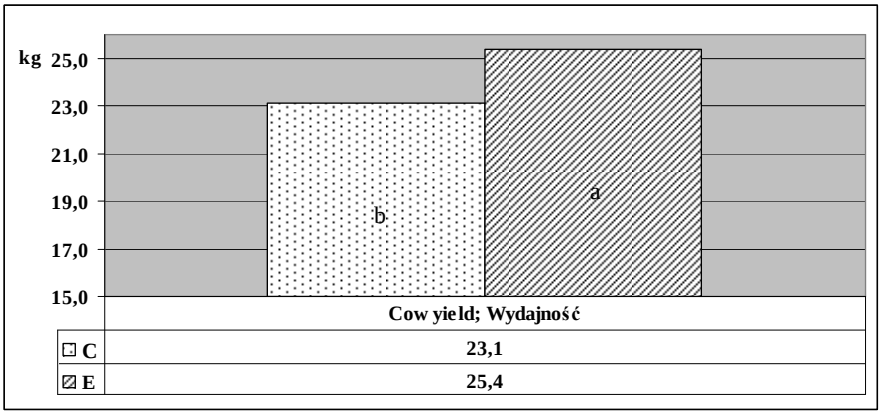
The main objective of dairy farming is to get optimum production of good quality milk, which depends on a number of factors, from cow health status, especially the mammary gland, through the entire milk processing technologies before it reaches a purchase point [Sawa 2004].

Table 4. Cow milk yield, composition and quality
Tabela 4. Wydajność, skład i jakość mleka krów

Index Wskaźnik	Group Grupa	Measurements in months 2010 and 2011 Pomiary w miesiącach 2010 i 2011 r.											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Yield, kg Wydajność, kg	C	20.2	24.2	27.4	24.4	22.8	24.6^{a}	23.9^{b}	21.2^{b}	22.6^{b}	22.4	20.0^{b}	22.4^{b}
	E	22.6	25.6	26.2	22.2	23.6	21.4^{b}	30.6^{a}	28.4^{a}	26.2^{a}	21.8	26.2^{a}	30.0^{a}
	SD	*2.17*	*2.03*	*1.78*	*2.14*	*1.91*	*2.98*	*5.18*	*5.23*	*3.27*	*2.12*	*3.96*	*4.87*
Dry master, % Sucha masa, %	C	12.2	12.4	12.3	12.5	12.3	12.1	12.2	12.2	12.4	12.3	12.5	12.3
	E	12.5	12.5	12.4	12.4	12.5	12.3	12.4	12.4	12.5	12.4	12.4	12.5
	SD	*0.17*	*0.13*	*0.21*	*0.10*	*0.22*	*0.37*	*0.45*	*0.51*	*0.34*	*0.29*	*0.39*	*0.28*
Lactose, % Laktoza, %	C	4.61	4.52	4.60	4.63	4.47	4.36^{b}	4.52	4.43	4.61	4.57	4.56	4.62
	E	4.71	4.80	4.80	4.64	4.62	4.73^{a}	4.82	4.73	4.79	4.91	4.82	4.80
	SD	*0.15*	*0.29*	*0.31*	*0.09*	*0.28*	*0.43*	*0.73*	*0.70*	*0.43*	*0.54*	*0.43*	*0.49*
Fat, % Tłuszcz, %	C	4.65	4.16^{b}	5.03^{a}	4.53	4.27	3.80^{b}	4.23^{a}	4.22	4.37	4.68	5.27^{a}	5.01^{a}
	E	4.73	4.75^{a}	4.31^{b}	4.57	4.66	4.51^{a}	3.81^{b}	4.05	4.21	4.94	4.42^{b}	4.50^{b}
	SD	*0.89*	*0.72*	*0.77*	*0.32*	*0.45*	*1.17*	*0.93*	*0.46*	*0.21*	*0.28*	*0.64*	*0.73*
Protein, % Białko, %	C	3.65	3.49	3.39	3.39	3.45	3.41	3.27	3.39	3.45	3.70	3.79	3.68
	E	3.66	3.58	3.39	3.24	3.30	3.48	3.34	3.40	3.57	3.61	3.39	3.57
	SD	*0.07*	*0.13*	*0.06*	*0.19*	*0.18*	*0.11*	*0.21*	*0.06*	*0.22*	*0.18*	*0.41*	*0.23*
SCC count, thousand ml^{-1} Liczba komórek som., tys. ml^{-1}	C	650	488	547^{a}	456	508	971^{a}	637^{a}	615^{a}	553^{a}	734^{a}	619	689^{a}
	E	588	579	278^{b}	457	520	507^{b}	522^{b}	405^{b}	300^{b}	489^{b}	591	323^{b}
	SD	*129*	*137*	*186*	*59*	*63*	*298*	*124*	*213*	*267*	*231*	*64*	*246*
Mean/Średnia													
Yield, kg Wydajność, kg		21.4^{B}	24.9^{AB}	26.8^{A}	23.3^{AB}	23.2^{AB}	23.0^{AB}	27.3^{A}	24.8^{AB}	24.4^{AB}	22.1^{B}	23.1^{AB}	26.2^{A}
Dry master, % Sucha masa, %		12.4	12.5	12.4	12.5	12.4	12.2	12.3	12.3	12.5	12.4	12.5	12.4
Lactose/Laktoza, %		4.66	4.66	4.70	4.64	4.55	4.55	4.67	4.58	4.70	4.74	4.69	4.71
Fat/Tłuszcz, %		4.69^{AB}	4.46^{AB}	4.67^{AB}	4.55^{AB}	4.47^{AB}	4.16^{B}	4.02^{B}	4.14^{B}	4.29^{AB}	4.81^{A}	4.85^{A}	4.76^{A}
Protein, % Białko, %		3.66	3.54	3.39	3.32	3.38	3.45	3.31	3.40	3.51	3.66	3.59	3.63
SCC count, thousand ml^{-1} Liczba komórek som., tys. ml^{-1}		619^{AB}	534^{B}	413^{B}	457^{B}	514^{B}	739^{A}	580^{AB}	510^{B}	427^{B}	612^{AB}	605^{AB}	506^{B}
Number of cows, unit Liczba krów, szt.	C	20	20	21	24	26	25	25	25	24	24	24	23
	E	24	26	26	24	29	31	30	29	26	26	27	31

C – control group/grupa kontrolna, E – experimental group/grupa eksperymentalna
$^{a, b, c}$ – values marked with different lowercase letters differ significantly between the groups with $p \leq 0.05$
$^{a, b, c}$ – wartości oznaczone różnymi małymi literami różnią się istotnie statystycznie pomiędzy grupami przy $p \leq 0,05$,
$^{A, B, C}$ – values marked with different capital letters differ significantly between months with $p \leq 0.05$
$^{A, B, C}$ – wartości oznaczone różnymi dużymi literami różnią się istotnie statystycznie pomiędzy miesiącami przy $p \leq 0,05$

An alarm signal indicating an early stage of the udder health state deterioration proves to be elevated somatic cell counts (SCC) in milk. Somatic cells, i.e. the cells of peeled off lactiferous alveolus epithelium, lactiferous ducts and sinus, leukocytes and lymphocytes penetrating into milk during milking practice are considered a major indicator of the herd body condition. The SC numbers are regarded as a udder health measure because leukocyte counts substantially increase in the milk from affected cows. Milk from healthy cows contains from 100 000 up to 400 000 SC/ml, however, the counts grow to several million at infection status. The SCC in milk, reflecting any changes in its biochemical composition, is widely accepted as a determinant method for milk quality and udder health evaluation. Therefore, prevention of milk SCC elevation appears to be the easiest and most cost-effective practice [Danków and Cais-Sokolińska 2003]. A somatic cell count increase may result from the nutrition mistakes, among others feeding poor quality diets [Kamieniecki *et al.* 2004]. If nutrient requirements of dairy cattle are not satisfied or feeding unstable then, not only milk yield depresses but overall animal immunity towards pathogens also impairs and consequently, disease incidence increases, especially mastitis [Weiss *et al.* 1990, Erskine and Bartlett 1993, Smith *et al.* 1997, Malinowski and Kłossowska 1999, Majewski *et al.* 2000]. Mastitis is a major disease affecting commonly high yielding cows and is associated with physiology of the cow mammary gland. It is estimated that the production of 1 liter of milk requires 500 liter of blood moving through the udder , which is enormous production effort [Kowalski and Kamiński 1999]. Nevertheless, a definite number of somatic cells is necessary and always present in milk and it may also change, subject to the physiological status of cow (lactation stage, gestation, oestrus) [Sawa *et al.* 2000, Danków and Cais-Sokolińska 2003]. Comparison of milk yield, its composition and quality throughout the research period has shown slight seasonal fluctuations in both, quantity and quality of milk (Tab. 4). At the same time, there was stated statistically significant improvement of the analyzed milk parameters, notably the lowered numbers of SC in the milk from cows receiving the experimental dietary additive.



[a, b] – values denoted with different letters are statistically significantly at $p \leq 0.05$
[a, b] – wartości oznaczone różnymi literami różnią się istotnie statystycznie przy $p \leq 0,05$

Fig.1. Comparison of average cow milk production
Rys. 1. Porównanie średniej wydajności mlecznej krów

The dietary MS supplementation at the amount of 50 g/d/animal has resulted in an overall increase in milk production and quality. Importantly, there was found significantly higher milk production performance of the cows from the experimental (E) group as compared to the control (C) (Fig. 1). Further, no significant differences in average content of fat, protein or lactose were recorded (Fig. 2). In most cases, mastitis develops when the innate immune system of the bovine mammary gland is compromised. However, resistance may be boosted and the immune system enhanced through the appropriate feeding strategy [Peterson and Dwyer 1998]. Poorly balanced diet in terms of the energy,

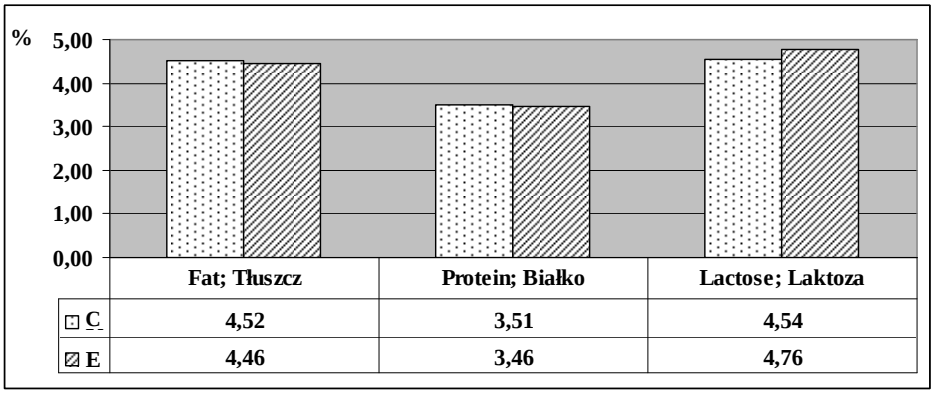
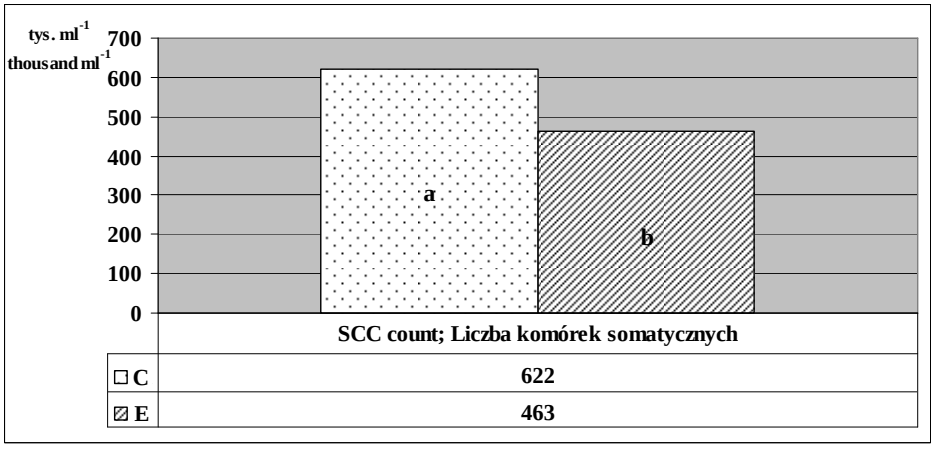


Fig. 2. Comparison of average fat, protein and lactose content in cow milk
Rys. 2. Porównanie średniej zawartości tłuszczu, białka i laktozy w mleku



a, b – values denoted with different letters are statistically significantly at $p \leq 0.05$
a, b – wartości oznaczone różnymi literami różnią się istotnie statystycznie przy $p \leq 0,05$

Fig. 3. Comparison of average SCC numbers in cow milk
Rys. 3. Porównanie średniej liczby komórek somatycznych w mleku krów

protein and antioxidants ratio as well as stress factor contribute to the impaired immune system [Bartnikowska 1992, Kowalski and Kamiński 1999]. The experimental additive tested was formulated to contain some vitamins and trace elements that favor the appropriate functioning of epithelial tissues, which in turn, promote animal resistance to minor infections within the udder as well as improve skin formations, like hooves, horns and hairs [Klebaniuk and Grela 2008, Weiss *et al.* 2010]. Such specific ”tightening” of the epithelium allows for reduction of infection incidence that translates into minimized immune responses in animal and consequently, lowers the counts of immune components, determined as somatic cells, that penetrate the cow milk. Hence, the most indicative effect of the experimental supplement (MS) application has proven to be the significantly decreased numbers of somatic cells determined in the milk from the cows under investigation (Fig. 3).

RESUME AND CONCLUSION

Bovine mastitis develops predominantly in immunocompromised cows. However, the natural self-defense mechanisms may be boosted and resistance strengthened through feeding a correct diet. Badly balanced dairy cattle rations in terms of energy, protein, minerals and vitamins, primarily of antioxidant properties, and exposure to stress have detrimental effect on the immune system functioning. Therefore, a key principle is implementation of a stable nutrition strategy based on well matched feedstuffs (quantity and quality) so that they can ensure maximum genetic performance achieved at reasonable economic costs. The rational system of cow feeding, with a special concern to animal age and lactation stage, is essential to maintain overall health status of cows and mammary gland in particular. Any nutritional mistakes in dairy cattle diet, i.e. imbalances in basic and mineral-vitamin nutrition have been shown to have negative impact on animal immune system and thus, can increase the risk for mastitis occurrence. For that reason, even well balanced feed rations need supplementation with some minerals, vitamins and other feed additives to optimize animal performance at good physical body condition.

In the present studies, the long-term and systematic administration of the experimental additive supplied at 50 g/d/unit resulted in the following:

1. A significant increase of cow milk yield.
2. Reduction in somatic cell counts in milk by ca. 25%.

Addition of mixture supplement (MS) at the amount of 50 g/d/unit to lactating cow feed rations may be recommended due to its beneficial impact on the cow health state, especially mammary gland and thus, improvement of the obtained milk quality.

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Streszczenie. Celem badań była ocena wpływu zastosowania komercyjnego dodatku mineralno-witaminowego do mieszanki uzupełniającej w żywieniu krów mlecznych, na wydajność, skład i jakość mleka. Badania przeprowadzono w gospodarstwie specjalistycznym, w okresie 24 miesięcy. Do badań wykorzystano krowy o wydajności powyżej 20 kg/dz., które na zasadzie analogów dobierano sukcesywnie, wraz z uzyskaniem oczekiwanej wydajności, do dwóch grup doświadczalnych: kontrolnej (K) oraz eksperymentalnej (E). Czynnikiem doświadczalnym był wprowadzony do TMR-u dla krów grupy E dodatek uzupełniający (MS). W czasie trwania badań oceniono skład, jakość i wartość pokarmową skarmianych pasz (co 2 miesiące) oraz wydajność, skład i jakość mleka krów (raz w miesiącu). W przeprowadzonych badaniach stwierdzono istotny wzrost wydajności krów otrzymujących w okresie laktacji dodatek mieszanki uzupełniającej MS w ilości 50 g/dz./szt. Stosowanie doświadczalnej mieszanki uzupełniającej ograniczyło liczbę komórek somatycznych w mleku o około 25%. Dodatek mieszanki uzupełniającej MS w ilości 50 g/dz./szt. do dawek dla krów podczas laktacji może być polecany jako pozytywnie wpływający na zdrowotność krów, a zwłaszcza wymienia, a tym samym poprawiający jakość pozyskiwanego mleka.

Słowa kluczowe: krowy, żywienie, dodatki mineralno-witaminowe, wydajność, jakość mleka, komórki somatyczne