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Influence of chosen factors on milk nutritional value

Wpływ wybranych czynników na wartość odżywczą mleka

Summary. The aim of the work was to evaluate the influence of chosen factors, i.e. cow's genotype, year seasons (feeding system), age (following lactation) and lactation phase on the nutritional value of milk.

The milk chemical composition was analyzed in six genetic groups of cows (in total, 2227 samples) maintained in the Lubelszczyzna Region and Bieszczady Mountains. It was found out that milk obtained from the Simmental cows had the most beneficial chemical composition. Those cows' milk also showed the highest protein-fat ratio (0.89%). In bovine milk from the autumn-winter season higher fat (4.51%) and protein concentration (3.68%), including casein (2.69%), was observed. However, in milk from spring-summer season more beneficial protein and fat proportion (0.85%) was noticed. With the progressing lactation, the concentration of fat (from 4.27% to 4.53%), protein (from 3.47% to 3.78%) casein (from 2.50% to 2.82%) and dry matter (from 13.22 to 13.67%) increased. Moreover, the protein-fat ratio increased (from 0.82 to 0.84) as well. The evaluation of the considered genetic-environmental interactions showed substantial variations ($P \leq 0.01$) in the breed and production season array for all analyzed milk characteristices, besides the casein content. In the arrangement of simultaneous influence of the four factors, i.e. breed and production season and lactation phase and the following lactation, no essential interactions were stated, apart from the lactose content ($P \leq 0.01$).

Key words: milk nutritional value, breed, cows' age, production season, lactation stage

INTRODUCTION

Milk, owing to its valuable and essential nutritional components, has a long tradition in human diet. Its competitive position with other foodstuffs has always been very strong as milk proved to satisfy all human nutritional requirements and is therefore recognized

as the most perfect food [Kozikowski and Przybyłowicz 1994, Rejman and Kowrygo 2002]. Milk entirely meets human demands for the highest quality protein as well as fat, disacharides, most vitamins, minerals and finally fatty acids, including polyunsaturated [Rafalski 1996; Bernatowicz and Reklewska 2003].

The number of milk constituents is very variable and the changes are subject to the genetic, physiological and environmental factors. The research-based assessment of factors affecting milk chemical composition revealed that genetic factors including breed, variety or individual traits account for the substantial (over half) part of the variation, the others being environmental and physiological elements, like nutrition, season of production, lactation stage, age of cow, etc. [Feleńczak *et al*. 2002, Barłowska *et al*. 2005]. Owing to the continued breeding management, the performance parameters were improved through genetic selection and, as a consequence, chemical composition of cows' milk varies significantly between different breeds. That refers mainly to fat and protein content and, in turn, protein/fat ratio(P/F) [Grega *et al*. 1998; Litwińczuk and Litwińczuk 2001]. The most important non-genetic factor proves to be nutrition. The desired milk composition can be obtained through appropriate choice of high-quality feeds, proper balance and suitable mineral-vitamin supplementation [Klocek *et al*. 1999]. Application of a given nutrition strategy offers the feasibility of obtaining alterations of milk composition so that the market and customers` demands could be met. According to Reklewski *et al*. [2002], more than 80% of cows in Poland are pastured and therefore milk obtained from that cows is richer in A vitamin as well β-caroten and unsaturated fatty acids. The lactation stage or a cow's age also affects the chemical composition of milk, its nutritive value and technological usability.

The objective of the present research was to determine the effect of chosen factors, i.e. cow's genotype, season of the year (feeding regime), age (successive lactation) and lactation stage on the basic milk constituents – determinants of milk nutritional value.

MATERIAL AND METHODS

The research material comprised milk obtained from cows maintained in two regions of Poland, namely Lubelszczyzna and the Bieszczady Mountains in 2003 and 2004. The investigations included 19 farms where over 20 cows were maintained, including 15 farms situated in the Lublin region and the other 4 farms in the Bieszczady. In all the cow barns, milk usefulness was checked. The studies involved 6 genetic groups of cows, i.e. Simental, Simental × Red-White crossbreds, Polish Holstein-Friesian (HF) Red-White variety up to 25% HO, Polish HF Red-White variety over 50% HO, Polish HF Black-White variety up to 50% HO, Polish HF Black-White variety over 50% HO. In the farms included into experiment, the following nutritional strategy was employed: spring-summer feeding system based mainly on pasture forage comprising grasses, legumines with hay and straw supplementation, while in autumn-winter season in Lubelszczyzna the animals received maize silage and haysilage and in the Bieszczady – haysilage predominantly with some additive of hay or straw. In all the farms, dietary units were rich feed-supplemented.

Milk for analysis was sampled from the same cows (if possible) throughout the experimental period, twice each season, that is the spring-summer period (V–VII) and the autumn-winter (XI–III).

Milk collected into plastic containers was then placed in the thermal containers to be transported to The Department of Commodity Science and Animal Material Processing and submitted to analyses. Each milk sample was examined for determination of the chemical composition, i.e. fat and protein percentage using Milko-Scan 104 apparatus; casein percentage according to Walker method PN-86/A-86122. The obtained results were analyzed considering the cow's genotype, season and age of cow distinguishing I lactation, II and III, IV, V, VI and the following as well as lactation stage, i.e. up to 120 day, over 200 day.

Data concerning the cows' genotype, age and lactation stage were obtained from the breeding records run by The National Animal Breeding Centre in Lublin.

The results were analyzed statistically using StatSoft Inc. STATISTICA ver.6 software system on the grounds of one- and multi-factor analysis of variance with interaction. Each trait was described with average values and standard deviation. Significance of differences between the means for the investigated groups was established by NIR Fischer`s test.

RESULTS AND DISCUSSION

The analysis of the basic chemical composition of milk presented in Table 1 showed that Black-White cows with over 50% HO genes and Simental x Red-White crossbreeds produced milk of the highest fat content (4.43–4.47%). Besides, the cows and their crosses with Red-White breed gave milk of the highest protein level (3.88 and 3.76%), including casein (2.73% each), lactose (4.77 and 4.82%) and dry matter (13.67 and 13.65%). The lowest concentration of these components were recorded in milk from Black-White breed with up to 50% HO genes (proteins – 3.40%, casein – 2.55%, lactose – 4.72% and dry matter 13.06%). Thus, the milk from Simentalers had the most beneficial chemical composition as compared to the other 5 genetic groups under study. The research results are consistent with the other authors' findings [Choroszy and Choroszy 2003, Feleńczak *et al*. 2003, Barłowska *et al*. 2004] that also confirm a high protein concentration in milk produced by the cows of Simental breed.

A high protein level with a low fat content in milk from Simentalers and their crosses with Red-White breed resulted in high protein/fat ratio that averaged 0.89 and 0.85 in those breed groups. In milk obtained from Polish HF Black-White breed, the proportion of these constituents appeared less advantageous and reached 0.81 (Tab. 1).

Grega *et al*. [2000] reported that protein/fat ratio in the milk from Simentalers was also high and ranged between 0.89 and 0.91. Kuczaj [2002a] analyzing among others, milk protein to fat ratio subject to the percentage of HF breed genes indicated that milk from cows with 26 up to 93% HF genes had the lowest P/F proportion – 0.78, whereas the highest in 100% HF breed animals (0.83).

Stanek et al. [2004] obtained a similar protein/fat ratio in milk from Black-White cows with varied HF gene share, which averaged 0.82.

Table 1. Cows' milk chemical composition of the analyzed genetic groups
Tabela 1. Skład chemiczny mleka krów analizowanych grup genetycznych

Genetic groups Grupa genetyczna	N	Statistical measures Miary statystyczne	Fat Tłuszcz %	Protein Białko %	Casein Kazeina %	Lactose Laktoza %	Dry matter Sucha masa %	P/F# B/T#
Simentaler	526	$\bar{x}$	4.36^{A}	3.88^{C}	2.73^{C}	4.77^{abc}	13.67^{C}	0.89^{A}
		SD	0.62	0.41	0.54	0.31	1.02	0.16
Simentaler × Red-White Simentaler × czerwono-biała	66	$\bar{x}$	4.43^{AB}	3.76^{BC}	2.73^{BC}	4.82^{c}	13.65^{BC}	0.85^{AB}
		SD	0.65	0.53	0.37	0.39	1.04	0.08
Polish Holstein-Friesian (HF) Red-White up to 25% HO Polski holsztyno-fryz odmiany czerwono-białej do 25% HO	140	$\bar{x}$	4.30^{A}	3.53^{AB}	2.62^{AB}	4.72^{a}	13.20^{A}	0.83^{B}
		SD	0.74	0.48	0.38	0.42	1.06	0.11
Polish HF Red-White over 50% HO Polski holsztyno-fryz odmiany czerwono-białej pow. 50% HO	197	$\bar{x}$	4.27^{A}	3.44^{A}	2.61^{AB}	4.73^{ab}	13.09^{A}	0.82^{B}
		SD	0.79	0.47	0.40	0.36	1.09	0.12
Polish HF Black-White up to 50% HO Polski holsztyno-fryz odmiany czarno-białej do 50% HO	126	$\bar{x}$	4.29^{A}	3.40^{A}	2.55^{A}	4.72^{a}	13.06^{A}	0.81^{B}
		SD	0.74	0.43	0.37	0.33	0.99	0.11
Polish HF Black-White over 50% HO Polski holsztyno-fryz odmiany czarno-białej pow. 50% HO	1172	$\bar{x}$	4.47^{B}	3.57^{AB}	2.67^{B}	4.78^{bc}	13.48^{B}	0.81^{B}
		SD	0.76	0.51	0.43	0.28	1.08	0.11

a, b, c – differences significant at $P \leq 0.05$, różnice istotne przy $P \leq 0{,}05$; A, B, C – differences significant at $P \leq 0.01$, różnice istotne przy $P \leq 0{,}01$
– protein-to-fat ratio, stosunek białka do tłuszczu

Table 2. Chemical composition of cows' milk produced in the spring-summer and autumn-winter seasons
Tabela 2. Skład chemiczny mleka krów produkowanego w sezonie wiosenno-letnim i jesienno-zimowym

Season Sezon	N	Statistical measures Miary statystyczne	Fat Tłuszcz %	Protein Białko %	Casein Kazeina %	Lactose Laktoza%	Dry matter Sucha masa %	P/F# B/T#
Spring-summer Wiosenno-letni	1303	$\bar{x}$	4.26^{A}	3.55^{A}	2.64^{a}	4.74^{A}	13.58^{B}	0.82^{a}
		SD	0.73	0.49	0.45	0.32	1.66	0.15
Autumn-winter Jesienno-zimowy	924	$\bar{x}$	4.51^{B}	3.68^{B}	2.69^{b}	4.81^{B}	13.27^{A}	0.85^{b}
		SD	0.72	0.44	0.45	0.30	1.02	0.12

a, b – differences significant at $P \leq 0.05$, różnice istotne przy $P \leq 0.05$; A, B – differences significant at $P \leq 0.01$, różnice istotne przy $P \leq 0{,}01$; # – protein-to-fat ratio, stosunek białka do tłuszczu

Table 3. Chemical composition of milk from cows in the following lactations
Tabela 3. Skład chemiczny mleka krów w kolejnych laktacjach

Following lactation Laktacja	N	Statistical measures Miary statystyczne	Fat Tłuszcz %	Protein Białko %	Casein Kazeina %	Lactose Laktoza %	Dry matter Sucha masa %	P/F# B/T#
I	504	$\bar{x}$	4.38	3.57	2.68^{ab}	4.84^{C}	13.44	0.82
		SD	0.75	0.53	0.48	0.30	1.10	0.11
II–III	804	$\bar{x}$	4.41	3.62	2.68^{b}	4.79^{B}	13.47	0.83
		SD	0.71	0.50	0.43	0.29	1.04	0.11
IV–V	551	$\bar{x}$	4.45	3.68	2.68^{ab}	4.72^{A}	13.50	0.83
		SD	0.73	0.52	0.42	0.32	1.19	0.16
VI and further VI i dalsze	368	$\bar{x}$	4.37	3.63	2.62^{a}	4.71^{A}	13.35	0.84
		SD	0.74	0.52	0.51	0.35	1.09	0.11

a, b – differences significant at $P \leq 0.05$, różnice istotne przy $P \leq 0{,}05$; A, B, C – differences significant at $P \leq 0.01$, różnice istotne przy $P \leq 0{,}01$; # – protein-to-fat ratio, stosunek białka do tłuszczu

Table 2 compares the results concerning the effect of the year season on milk chemical composition, which is associated with the feeding system employed to a large extent. It was demonstrated that milk gained from cows in the autumn-winter season had a significantly higher fat content (4.51%) and the protein level (3.68%), including casein (2.69%) as compared to milk from the spring-summer period with respective values – 4.26, 3.55 and 2.64%. However, milk produced in the spring-summer season, despite a decreased level of protein and fat, was characterized by significantly more beneficial ($P \leq 0.05$) ratio of these constituents (0.85) as compared to the autumn-winter period (0.82). Besides, milk obtained over the spring-summer season contained more lactose by 0.07% ($P \leq 0.01$).

Table 4. Chemical composition of the milk of cows in the following lactation stages
Tabela 4. Skład chemiczny mleka krów w kolejnych fazach laktacji

Lactation stage Faza laktacji	N	Statistical measures Miary statystyczne	Fat Tłuszcz %	Protein Białko %	Casein Kazeina %	Lactose Laktoza %	Dry matter Sucha masa %	P/F# B/T#
Up to 120 day Do 120 dnia	709	$\bar{x}$	4.27^{A}	3.47^{A}	2.50^{A}	4.83^{C}	13.22^{A}	0.82
		SD	0.70	0.51	0.38	0.26	1.03	0.16
121–200 day 121–200 dni	611	$\bar{x}$	4.38^{B}	3.59^{B}	2.65^{B}	4.78^{B}	13.40^{B}	0.83
		SD	0.75	0.49	0.42	0.31	1.07	0.11
Over 200 day Powyżej 200 dnia	907	$\bar{x}$	4.53^{C}	3.78^{C}	2.82^{C}	4.71^{A}	13.67^{C}	0.84
		SD	0.72	1.55	0.48	0.35	1.83	0.29

A, B, C – differences significant at $P \leq 0.01$, różnice istotne przy $P \leq 0{,}01$; # – protein-to-fat ratio, stosunek białka do tłuszczu

Sawa *et al*. [2000] informed that in the autumn months (IX–XI), fat and protein concentration appeared higher, i.e. 4.52 and 3.43% as compared to the summer (VI–VIII) – 3.84 and 3.29%.

Barłowska *et al*. [2004], who evaluated milk obtained from Simentalers found that protein percentage in the autumn-winter season was higher by 0.09. As for fat concentration, no significant differences were recorded.

Stanek *et al*. [2004] reported a higher level of dry matter (13.53%), fat (4.45%) and protein (3.53%) in the autumn-winter period as compared to milk from cows assessed in the spring-summer season (13.18; 4.21; 3.36%).

Table 3 summarizes the results concerning the basic milk quality parameters, totally for all the cow breed groups in the successive lactations.

It was found that heifers produced milk of the lowest fat content (4.38%) and protein level (3.57%). The peak milk production recorded in IV and V lactations correlated with the highest fat concentration (4.45%), protein (3.68%) and dry matter (13.50%). In the following lactations, that is over V lactation, the content of each milk constituent decreased. It was also shown that milk lactose level declined with cow age ($P \leq 0.01$) and protein/fat ratio tended to rise (from 0.82 up to 0.84). Casein concentration recorded in cows in the first five lactations appeared to be constant and averaged 2.68%. In the older animals, though, it decreased to 2.62% ($P \leq 0.05$).

Litwińczuk *et al*. [2003], evaluating the impact of the successive lactation on the yield and concentration of basic constituents of milk from Simentalers reported the highest fat and protein concentration in II lactation with average values of 3.84 and 3.47%.

Kuczaj [2002b] studied the daily milk yield, its chemical composition and somatic cell count (SCC) in Black-White cows in the successive three lactations and found that the highest milk performance was recorded for the cows in III lactation – 55.63 kg, while the highest milk fat content (4.50%) for heifers and protein concentration (3.21%) for cows being in II lactation.

Sawa *et al*. [2000] reported the highest efficiency of the cows in III lactation (6046 kg), whereas fat and protein yields appeared to be the highest in II lactation, 4.22 and 3.27%. respectively.

Table 5. Final results of the quaternary-factors variance analysis of the milk chemical composition
Tabela 5. Końcowe wyniki czteroczynnikowej analizy wariancji dla składu chemicznego mleka

Factor Czynnik	Fat Tłuszcz %	Protein Białko %	Casein Kazeina %	Lactose Laktoza %	Dry matter Sucha masa %	P/F# B/T#
Breed Rasa	xx	xx	xx	x	xx	xx
Season of production Sezon produkcji	xx	x	x	xx	xx	x
Lactation stage Faza laktacji	xx	xx	xx	xx	xx	ns
Following lactation Kolejna laktacja	ns	ns	x	xx	ns	ns
Interaction breed × season of production Interakcja rasa × sezon produkcji	xx	xx	ns	xx	xx	xx
Interaction breed × following lactation Interakcja rasa × kolejna laktacja	ns	ns	ns	x	ns	ns
Interaction breed × stage lactation Interakcja rasa × faza laktacji	x	ns	ns	xx	ns	ns
Interaction season of production × lactation stage Interakcja sezon produkcji × faza laktacji	ns	ns	xx	ns	ns	ns
Interaction season of production × following lactation Interakcja sezon produkcji × kolejna laktacja	ns	ns	ns	ns	ns	ns
Interaction lactation stage × following lactation Interakcja faza laktacji × kolejna laktacja	ns	ns	ns	ns	ns	ns
Interaction breed × season of production × following lactation Interakcja rasa × sezon produkcji × kolejna laktacja	ns	ns	ns	x	ns	ns
Interaction breed × season of production × lactation stage Interakcja rasa × sezon produkcji × faza laktacji	ns	ns	ns	x	ns	ns
Interaction season of production × lactation stage × following lactation Interakcja sezon produkcji × faza laktacji × kolejna laktacja	ns	ns	ns	ns	ns	ns
Interaction breed × season of production × lactation stage × following lactation Interakcja rasa × sezon produkcji × faza laktacji × kolejna laktacja	ns	ns	ns	xx	ns	ns

– protein-to-fat ratio, stosunek białka do tłuszczu; interactions: x – differences significant at $P \leq 0.05$, różnice istotne przy $P \leq 0,05$; xx – differences significant at $P \leq 0.01$; różnice istotne przy $P \leq 0,01$; ns – not recorded, nie stwierdzono różnic

The analysis of lactation stage influencing milk chemical composition was carried out for the whole cows' population (Tab. 4). It revealed a gradual rise of concentration

of fat (from 4.27 up to 4.53%), protein (3.47–3.78%), casein (2.50–2.82%) and dry matter (13.22–13.67%) with advancing lactation. Besides, the protein/fat proportion was shown to increase (from 0.82 up to 0.84), yet the difference was not statistically significant. Only lactose content tended to decline, that is from 4.83 to 4.71%. On the othe hand, a significant decrease in late lactation was observed in milk urea level ($P \leq 0.01$). According to Litwińczuk and Litwińczuk [2000] bovine milk protein yield and concentration are highly correlated with the lactation stage. Normally, milk protein content decreases between 3rd and 50th post calving days and gradually increases towards the end of the lactation period.

Stenzel *et al*. [2003], analyzing the following lactation influence and its process on the daily yield changes, milk content and the somatic cells namber, showed the fat content decrease (from 4.25% for cows' being in I lactation to 4.17% for V, and protein from 3.51% for II to 3.39%, respectively. The studies of Barłowska *et al*. [2005] are consistent with the finding that, irrespective of breed, progressing lactation induces the growth of fat, protein, casein and dry matter yields as well as an elevated protein/fat ratio. However, milk lactose level declines.

CONCLUSIONS

1. It was proved that out of 6 analyzed genetic groups of cows, Simentalers produced milk of most advantageous chemical composition.

2. Milk obtained from cows in the fall and winter periods was characterized by significantly higher yields of fat (4.51%) and protein (3.68%), including casein (2.69%) as compared to milk from the spring-summer period with these milk constituents – 4.26; 3.55; 2.64%, respectively. However, it had a significantly less beneficial protein/fat ratio (0.82) as against the spring-summer season (0.85).

3. Heifers were shown to produce milk of the lowest content of fat (4.38%) and protein (3.57%). The peak milk production usually recorded in IV and V lactations correlated to the highest fat level (4.45%), protein (3.68%) and dry matter (13.50%). Besides, it was found that with cow age advancing, milk lactose level was decreasing, while protein/lactose proportion tended to rise (from 0.82 up to 0.84). Milk casein concentration remained constant throughout the first five lactations and averaged 2.68% and it was decreased to 2.62% in older animals.

4. With progressive lactation, a rising concentration of fat (from 4.27 to 4.53%), protein (3.47–3.78%), casein (2.50–2.82%) and dry matter (13.22–13.67%) in milk was detected. Protein/fat ratio was also elevated (from 0.82 to 0.84%). Only lactose concentration showed a downward trend (from 4.83 to 4.71%).

The article is based on a doctoral dissertation.

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Streszczenie. Celem pracy było określenie wpływu wybranych czynników, tj. genotypu krowy, pory roku (systemu żywienia), wieku (kolejnej laktacji) i fazy laktacji na wartość odżywczą mleka.

U 6 grup genetycznych krów utrzymywanych na Lubelszczyźnie i w Bieszczadach analizowano skład chemiczny mleka (łącznie 2227 prób). Wykazano, że mleko pozyskiwane od krów rasy simentaler charakteryzowało się najkorzystniejszym składem chemicznym, tj. zawartością białka 3,88%, w tym kazeiny 2,73%, laktozy 4,77% oraz suchej masy 13,67%. Mleko tych krów odznaczało się również najwyższym stosunkiem białkowo-tłuszczowym (0,89%). Sezon produkcji miał także wpływ na skład chemiczny mleka. Stwierdzono, że w mleku z sezonu jesienno-zimowego była większa koncentracja tłuszczu (4,51%) i białka (3,68%), w tym kazeiny (2,69%). Natomiast mleko z sezonu wiosenno-letniego charakteryzowało się istotnie korzystniejszą proporcją białka i tłuszczu (0,85%). Wiek krowy również miał wpływ na zawartość podstawowych składników mleka. Szczyt produkcyjny przypadał z reguły na IV–V laktację, co łączyło się z największą zawartością tłuszczu (4,45%), białka (3,68%), i suchej masy (13,50%). Analiza wpływu fazy laktacji na skład chemiczny mleka wykazała, że wraz z jej przebiegiem wzrastała koncentracja tłuszczu (z 4,27 do 4,53%), białka (z 3,47 do 3,78%), kazeiny (z 2,50 do 2,82%) i suchej masy (z 13,22 do 13,67%). Podwyższeniu ulegał również stosunek białkowo-tłuszczowy (z 0,82 do 0,84).

Słowa kluczowe: wartość odżywcza mleka, rasa, wiek krów, sezon produkcji, faza laktacji