ISSN 1644-0714
ISSN 2300-6145 (online)
www.asp.zut.edu.pl

ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol. Zootechnica 14(4) 2015, 131–140*

EFFECT OF SEASON AND PRODUCTION SYSTEM ON BOVINE MILK FAT CONTENT AND DISPERSION

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Abstract. We analyzed the effect of dairy cows management system and season on milk fat content and dispersion. The milk was collected from HF cows, Black-and-White variety, managed in 7 production farms located in central-eastern Poland. Two of the farms managed the cows in confinement (total 60 cows), whereas five other farms managed the cows in a traditional way (total 75 cows). Milk was sampled from individual cows separately during summer and winter seasons. In summer, 51 samples were collected, whereas in winter – 84 milk samples. In all, we have collected 135 milk samples. Each sample was analyzed for percentage fat content and the number and diameter of fat globules.

Comparing the results of the two studied seasons studies it was found that during summer cows produce milk with a lower fat content (4.2%), though containing a higher number of fat globules in 1 ml (4.4 billion), as compared to the winter season (respectively, 4.6% and 3 billion). The differences in the percentage of fat were significant at $P \geq 0.01$, while those in the number of fat globules were significant at the level of $P \geq 0.05$. During the summer, we also observed a smaller percentage (6%) of the largest fat globules, i.e. those >6 μm in diameter, compared to winter (10.3%). The differences, however, were statistically non-significant. Analyzing the results of the two management systems, we noted that the cows housed in the traditional system produced milk with a lower fat percentage (4.3%) and containing more fat globules in 1 ml (3.8 billion), as compared to confinement housing (respectively, 4.5% and 3.4 billion). The differences in the percentage fat content were significant at $P \geq 0.05$, while differences in the number of fat globules at $P \geq 0.01$. Milk from cows managed in the traditional system was characterized by a lower content (8%) of large fat globules compared to milk of cows housed in confinement, where the such globules represented 9.2%. The differences were non-significant.

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Key words: season, management systems, milk, fat globules

INTRODUCTION

One of the main objectives of the dairy sector is to improve the technological quality and nutritional values of milk. Fat represents a very important component of milk. Its composition is a key factor in terms of the nutritional value, digestibility – which can reach up to 99% – and the pleasant taste of milk [Barłowska et al. 2005 Cichosz and Czeczot 2014, Garcia et al. 2014 Smoczyński et al. 2012]. Fatty acids, more then 400 of which have been detected in milk fat, determine the quality of the fat; their properties depend on the hydrocarbon chain length and number of unsaturated bonds [Barłowska and Litwińczuk 2009].

Fat in milk is in the form of small, highly dispersed droplets or globules which form the emulsion. Each milliliter of bovine milk contains from 2 to 6 billion fat globules of dimensions of from 0.1 to 20 μm in diameter. Most, about 80% of the globules, are 2–6 μm in diameter. Individual globules of milk fat are covered by membranes that prevent them from confluence [Barłowska and Litwińczuk 2009, Barłowska et al. 2005, Jurczak 2005]. These coatings are composed of a range of substances, proteins, phospholipids, neutral glycerides, cholesterol, enzymes, carotenoids and vitamins [Menard et al. 2010, Michalski et al. 2004, Smoczyński al. 2012].

Our research confirmed that the size of fat globules affects the quality of dairy products. This is strictly related to the quality and quantity of the membrane material and its properties, such as resistance to thermal and mechanical treatment, or water binding capacity [Kordyasz 2012, Menard et al. 2010]. Gaudedranche al. [2000] report that cheese produced from milk containing smaller fat globules is softer compared to that obtained from raw milk having larger size of fat particles. Additionally, smaller fat globules are more easily available for bacterial enzymes during milk fermentation and maturation. They influence thereby the palatability and texture of the final product. The membranes of larger globules are more damage prone, so the fat undergoes lipolysis sooner than it would otherwise, which results in a rancid aftertaste. Small globules, on the other hand, are more stable, since destruction of their membranes requires more energy [Kordyasz 2012, Kuczaj et al. 2011, Wiking et al. 2003].

A number of studies point to the health-promoting properties of milk fat and the constituents of globular membranes, which include high digestibility, antioxidant, anticarcinogenic and anti-adhesion effects, microbial barrier, defense mechanism in newborns [Ahn et al. 2011, Barłowska and Litwińczuk 2009, Garcia et al. 2014, Smoczyński et al. 2012]. According to Cichosz and Czeczot [2014], all components of milk fat, also those regarded as bad saturated fatty acids, reveal

a high level of biological activity. The authors propose that milk fat is the most important dietary fat in human diet.

Studies carried out in recent years have shown that there are a number of factors that affect the amount of milk fat, its composition and the degree of dispersion [Kuczaj et al. 2011, Litwińczuk et al. 2014, Marcondes et al. 2014, Miciński et al. 2012, Popović-Vranješ et al. 2011, Rutkowska et al. 2012]. Experiments confirmed there is an effect of breed, age and lactation stage on the size of the fat globules in milk [Barłowska et al. 2014, Barłowska et al. 2005a, Barłowska et al. 2005b, Logan et al. 2014]. Barłowska et al. [2005a] stated that amongst three breeds of cows (Red-and-White, Black-and-White and Simmental), Simmental cows produced milk with the highest number of large fat globules and Black-and-White cows – the lowest number. The milk of Simmental cows also contained most unsaturated fatty acids and the highest content of conjugated linoleic acid (CLA) in relation to total FAs. Studies also show the proportion of small fat globules in the milk of cows increases with the lactation progress [Barłowska et al. 2005a, Barłowska et al. 2005b]. Wiking et al. [2003] and Menard et al. [2010] found a correlation between the percentage of milk fat and the size of fat globules. Wolanciuk et al. [2013] noted an effect of cow's milk yield on the size of the fat globules. With higher milk yields, the activity of milk-secreting cells synthesizing the membrane material decreases and, in consequence, the diameter of the fat globules grows.

Many authors confirm in their reports that there is the relationship between the size of fat globules and their composition [Menard et al. 2010, Mesilati-Stahy et al. 2011, Michalski et al. 2005]. Experiments clearly show that small particles of fat in bovine milk contain more unsaturated fatty acids, including so desired CLA, as compared to large globules [Chen et al. 2014, Couvreur et al. 2007, Michalski et al. 2004].

The aim of this study was to determine the effect of season and management system of cows on milk fat content and on the numbers and size of fat globules.

MATERIAL AND METHODS

The study was carried out in the summer and winter of 2008, in seven farms located in the central-eastern part of Poland. In the summer, milk samples were collected from 51 cows, whereas in the winter from 84 cows. All the studied farms were under a cow milk performance evaluation program. Two of the farms managed the cows in the confinement system (TMR feeding), where the complete ration was dispensed by an automatic feeder and the other feedstuffs, such as corn silage, haylage, or beet pulp, were fed manually. In this production system, we collected 60 milk samples. In five other farms, cows were reared in a traditional,

semi-confinement (pasture and confinement) management system. In summer, the cows grazed on pasture, where they were also fed grain and, temporarily, straw. In winter, on the other hand, cows were offered haylage, corn silage, beet pulp, complete ration and supplements. From this management system, we collected 75 samples of milk. Milk samples were collected from 24-hour milking, separately from each cow. In all, we collected 135 samples, which were analyzed for percentage fat content and the number and size of fat globules. The percentage of fat was measured with the MilkoScan analyzer, while the number and size of the fat globules in the milk were determined using a microscope equipped with a stage and ocular micrometer scales. Slides were prepared using quantitatively diluted milk applied on a calibrated Thoma chamber. Slides were viewed at a magnification 600x. Globules were classified within one of three size intervals: <3 μm, 3–6 μm and >6 μm. We calculated the percentage of each class of fat globules size in relation to their total number.

The statistical analysis of data involved one-way ANOVA, with Tukey's test for the significance of differences. The following were included in the calculations:

1. Production season:
– summer
– winter
2. Management system:
– traditional
– confinement (TMR)

Based on the collected data, we estimated the effects of production season and the management systems on the percentage milk fat content and the number and diameter of fat globules.

RESULTS AND DISCUSSION

The average fat content in the milk of the studied HF/Black-and-White variety cows was 4.4% and the number of fat globules was 3.6 billion in 1 ml. We found significant effects of the season ($P \leq 0.01$) and management system ($P \leq 0.05$) on milk fat content (Table 1 and Table 2).

A higher level of fat content (4.6%) was observed in the winter, whereas in the summer it was by 0.4% lower in the analyzed milk samples. Also cows kept in the confinement system produced milk richer in fat, 4.5%, as compared with those managed in a traditional way, which produced milk averaging 4.3% fat. With an increase in fat content in milk, the number of fat globules decreased. In the winter, the number of globules was significantly ($P \leq 0.01$) lower compared to the summer season (respectively, 3.0 billion and 4.4 billion in 1 ml of milk) (Table 1). The

Table 1. Content of fat (%) and quantity of fat globules (billion · ml^{-1}) in milk by season

Tabela 1. Zawartość tłuszczu (%) i liczba kuleczek tłuszczowych (mld · ml^{-1}) w mleku w zależności od sezonu

Season – Sezon	N	Content of fat (%) Zawartość tłuszczu (%)		Liczba kuleczek tłuszczowych (billion · ml^{-1}) Amount of fat globules (mld · ml^{-1})	
		Mean – Średnia	SD	Mean – Średnia	SD
Summer – Lato	51	4.2A	0.9	4.4B	0.9
Winter – Zima	84	4.6B	0.8	3.0A	0.6
Total – Ogółem	135	4.4	0.9	3.6	0.6

A, B – differences significant at $P \leq 0.01$.
A, B – różnice istotne na poziomie $P \leq 0{,}01$.

Table 2. Content of fat (%) and quantity of fat globules (billion · ml^{-1}) in milk by management system

Tabela 2. Zawartość tłuszczu (%) i liczba kuleczek tłuszczowych (mld · ml^{-1} mleka) w mleku w zależności od systemu produkcji.

Management system System utrzymania	N	Content of fat (%) Zawartość tłuszczu (%)		Amount of fat globules (mld · ml^{-1}) Liczba kuleczek tłuszczowych (billion · ml^{-1})	
		Mean – Średnia	SD	Mean – Średnia	SD
Traditional – Tradycyjny	75	4.3a	0.8	3.8B	0.2
Confinement – Alkierzowy	60	4.5b	1.0	3.4A	0.5
Total – Ogółem	135	4.4	0.9	3.6	0.6

A, B – differences significant at $P \leq 0.01$; a, b – differences significant at $P \leq 0.05$.
A, B – różnice istotne na poziomie $P \leq 0{,}01$; a, b – różnice istotne na poziomie $P \leq 0{,}01$.

same relationship was observed in terms of the production system. At higher milk fat content (4.5%) obtained from the confinement system, a lower number of fat globules (3.4 billion · ml^{-1}) in comparison with the traditional system (4.3% and 3.8 billion · ml^{-1}). Here, the differences also proved to be significant at $P \leq 0.01$ (Table 2). A similar average fat content (4.36%) in the milk of HF, Black-and-White variety cows in spring and summer have been reported by Barłowska et al. [2005a]. Fat content in milk of this breed of cows reported by other authors ranged from 4.04% to 4.54% [Barłowska et al. 2014, Barłowska et al. 2005b, Chen et al. 2014]. Research conducted by Cimen et al. [2013] also point to the lowest fat content of milk in July and August. The authors report about a "fat depression" in bovine milk during summer. Marcondes et al. [2014] compared bovine milk component in relation to various production systems. They results correspond to those obtained in our study. Milk produced under traditional production system contained less fat, as compared with milk of cows managed in the confinement system.

The data presented in Table 3 reveal considerable differences in the number of fat globules between particular milk samples in relation to year season.

Table 3. The distribution of analyzed material by amount of fat globules and season

Tabela 3. Rozkład badanego materiału na klasy wg liczby kuleczek tłuszczowych w mleku w sezonie letnim i zimowym.

Amount of fat globules (billion · ml^{-1}) Liczba kuleczek tłuszczowych (mld · ml^{-1})	Season – Sezon				Total – Razem	
	Summer – Lato		Winter – Zima			
	N	%	N	%	N	%
<3.00	1	2.0	40	47.6	41	30.4
3.01–4.00	15	29.4	38	45.2	53	39.3
4.01–5.00	24	47.1	5	6.0	29	21.5
>5.00	11	21.5	1	1.2	12	8.8
Total amount of samples – Razem liczba prób	51	100.0	84	100.0	135	100.0

$\chi^2 = 63.57$**

In the summer, only one sample contained up to 3 billion fat globules in 1 ml, which represented 2% of the overall material. In the winter, on the other hand, such samples represented nearly 50%. Milk samples with the highest unit number of fat globules (>5 billion · ml^{-1}) represented 20% of the total in the summer, and as little as 1% in the winter.

Considering the size of fat globules in the overall material, it has been found that the analyzed milk contained most fatty globules averaging 3–6 μm in diameter, 53.9%. The smallest part, 8.5%, was represented by the largest globules, 6 μm in diameter (Table 4 and Table 5). According to Logan et al. [2014], bovine milk most often contains fat globules of 2.5 to 5.7 μm in size.

Table 4. The distribution of analyzed material according to diameter of fat globules in seasons.

Tabela 4. Rozkład badanego materiału na klasy wg średnicy kuleczek tłuszczowych mleka w sezonie letnim i zimowym.

Diameter of fat globules (μm) Średnica kuleczek tłuszczowych (μm)	Season – Sezon				Total – Razem	
	Summer – Lato		Winter – Zima			
	N	%	N	%	N	%
<3	2584	58.1	1461	23.1	4046	37.6
3–6	1599	35.9	4211	66.6	5810	53.9
>6	266	6.0	648	10.3	914	8.5
Number of measured globules Liczba zmierzonych kuleczek	4450	100.0	6320	100.0	10770	100.0
Total amount of samples Razem liczba prób	51		84		135	

$\chi^2 = 5548.6$**

Table 5. The distribution of analysed material according to diameter of fat globules in different management system.

Tabela 5. Rozkład materiału wg średnicy kuleczek tłuszczowych w mleku w zależności od systemu utrzymania krów

Diameter of fat globules (μm) Średnica kuleczek tłuszczowych (μm)	Management system – System utrzymania				Total – Razem	
	Traditional Tradycyjny		Confinement Alkierzowy			
	N	%	N	%	N	%
<3	2420	38.3	1626	36.5	4046	37.6
3–6	3389	53.7	2421	54.3	5810	53.9
>6	504	8.0	410	9.2	914	8.5
Number of measured globules Liczba zmierzonych kuleczek	6313	100.0	4457	100.0	10770	100.0
Total amount of samples Razem liczba prób	75	60	135	75	60	135

$\chi^2 = 5459.8^{**}$

In terms of season-related size distribution of fat globules, we found that the smallest particles (< 3 μm) represented nearly 60% in the summer and a little more than 20% in the winter. In summer, the largest globules constituted 6%; in winter, however, there were more of them, 10.3% (Table 4). A similar relationship was found by Barłowska et al. [2014]. In the milk from the spring-summer season, the number of large fat globules was over 4% lower than in the milk from the autumn-winter season.

Considering the size distribution of the different classes of fat globules in milk, depending on the production system of cows (Table 5), there was a higher proportion (9.2%) of the largest globules (> 6 μm) in bovine milk from the confinement system, compared with milk derived from cows maintained the traditional system, where the largest fat particles represented 8.0%.

CONCLUSIONS

1. In the summer, cows produced milk with a lower fat content though containing a higher number of fat globules, in comparison with the milk produced during the winter season. There were more smaller fat globules in the milk from the summer season.

2. The milk produced by cows managed in the semi-confinement system was characterized by a lower percentage content of fat, contained more fat globules of smaller size, as compared to the milk from cows kept in the confinement system.

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WPŁYW SEZONU I SYSTEMU UTRZYMANIA KRÓW NA ZAWARTOŚĆ TŁUSZCZU W MLEKU I STOPIEŃ JEGO DYSPERSJI

Streszczenie. W pracy analizowano wpływ systemu utrzymania krów oraz pory roku na zawartość tłuszczu w mleku i stopień jego dyspersji. Mleko pochodziło od krów rasy HF odmiany cb, utrzymywanych w 7 gospodarstwach indywidualnych środkowowschodniej Polski. Dwa gospodarstwa utrzymywały krowy systemem alkierzowym (łącznie 60 krów), natomiast w pięciu krowy były utrzymywane tradycyjnie (łącznie 75 krów). Próbki mleka pobierano osobno od każdej krowy w okresie letnim i zimowym. Latem pobrano 51 prób, natomiast zimą 84 prób mleka. Łącznie pobrano 135 prób mleka. W każdej próbie mleka oznaczano procentową zawartość tłuszczu oraz liczbę i średnicę kuleczek tłuszczowych.

Porównując wyniki z dwóch sezonów badań, stwierdzono, że krowy w okresie letnim produkowały mleko o niższej zawartości tłuszczu (4,2%), ale o większej liczbie kuleczek tłuszczowych w 1 ml (4,4 mld) w porównaniu z sezonem zimowym (odpowiednio: 4,6% i 3 mld). Różnice w procentowej zawartości tłuszczu kształtowały się na poziomie $P \geq 0{,}01$, natomiast różnice w liczbie kuleczek tłuszczowych, na poziomie $P \geq 0{,}05$. Latem zaobserwowano też mniejszy udział (6%) niż zimą (10,3%) największych kuleczek tłuszczowych, o średnicy >6 μm. Różnice nie były jednak statystycznie istotne. Analizując wyniki z dwóch systemów utrzymania, odnotowano, że krowy utrzymywane w systemie tradycyjnym produkowały mleko o niższej procentowej zawartości tłuszczu (4,3%) i większej liczbie kuleczek tłuszczowych w 1 ml (3,8 mld) w porównaniu z systemem alkierzowym (odpowiednio: 4,5% i 3,4 mld). Różnice w procentowej zawartości tłuszczu kształtowały się na poziomie $P \geq 0{,}05$, natomiast różnice w liczbie kuleczek tłuszczowych, na poziomie $P \geq 0{,}01$. Mleko pochodzące od krów utrzymywanych systemem tradycyjnym charakteryzowało się mniejszym udziałem (8%) dużych kuleczek tłuszczowych w porównaniu do mleka krów z systemu alkierzowego, gdzie kuleczek takich odnotowano 9,2%. Różnice były statystycznie nieistotne.

Słowa kluczowe: sezon, system utrzymania, mleko, kuleczki tłuszczowe

Accepted for print: 10.11.2015

For citation: Mróz, B., Górska, A., Adamiak, A. (2015). Effect of season and production system on bovine milk fat content and dispersion. Acta Sci. Pol. Zootechnica, 14(4), 131–140.