Technological Properties of Milk from The Cows of Black-Motley and Alatau Breeds in Various Seasons of Lactation

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***Abstract*: The productivity of a dairy herd and the quality of milk largely depend on the biological and managerial factors used at dairy farms. Milk producers are not only interested in getting more milk, but also in ensuring its high quality and basic indices of the composition, particularly fat and protein percentage, which determines the consumption of raw materials and output of the finished products, their quality, and nutritional value. It is well known that the breed, the age, the nutrition and the health status of lactating animals determine the milk yield and milk composition. However, various breeds of cattle have different productivities and the content of the main components.**

The study was aimed at obtaining the information about, and assessing the influence of the breed and season-related changes on the physicochemical characteristics of milk, and at predicting the effect of these changes on the composition and the quality of such milk products.

For assessing the differences in milk from various breeds, and assessing the effect of the season on the quality, the physicochemical parameters, including the content of fatty acids, of the milk from black-motley and Alatau cows of Kazakhstan were studied. To assess the health status of lactating animals, the content of somatic cells in the milk was assessed.

The results show that the season and the breed significantly influence the physicochemical characteristics of milk and the content of fatty acids in lipids.

***Index Terms*: breed, fatty acid composition of cow milk, season.**

I. INTRODUCTION

Cow milk is an important component of human nutrition. Its composition and quality are crucial in obtaining the products of its processing. Milk composition is very variable, depending on the conditions of breeding and feeding, management strategies, herd, stage of lactation, and the season of the year. According to [1], cow milk contains about 87 % of water, 4.6 % of lactose, 3.4 % of protein, 4.2 % of fat, 0.8 % of minerals, and 0.1 % of vitamins.

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The main components that directly influence eating qualities and technological properties of milk are milk protein, fat, and lactose. The actual content of the main components in commercial milk may vary within a rather wide range: protein – between 2.8 and 3.6 %, fat – between 2.8 and 6 %, and lactose – between 4.5 and 4.8 %.

Milk fat is one of the fats that are the most valuable to the human organism [2-5]. The fat in cow milk is the basis of such products as butter, melted butter, and sour cream. Its share is high in curd and cheese. It acts not only as a plasticizer, but also as a source of many participants in the process of forming the flavor of dairy products. More than 98 % of the total fat in milk is the share of triacylglycerols; the remainder consists of monoacylglycerol and diacylglycerol, free fatty acids, phospholipids, sterols, carotenoids, fat-soluble vitamins, and flavor compounds [6].

In dairy cows, the typical composition of fatty acids is represented by acids of various composition, about 70 % of them are saturated fatty acids (SFA), 25 % are monounsaturated fatty acids (MUFA), and 5 % are polyunsaturated fatty acids (PUFA), which is significantly different from the ideal profile of fatty acids for human health [7].

The fatty acid composition of milk fat has a significant effect on its nutritional and biological value and the technological properties of milk [8]. In milk, fatty acids are formed almost equally from two sources: the fodder and the microbial activity in the rumens of cows [9]. The fatty phase also includes phospholipids (phosphatidylcholine, sphingomyelin, etc.), glycolipids (cerebrosides), sterols, and their ethers [10].

In the nature, over 200 fatty acids have been identified, but in the tissues of humans and animals, about 70 fatty acids have been found in simple and complex lipids; more than half of them being in trace amounts. In practice, slightly more than 20 fatty acids are the most widely spread. Highest fatty acids with an even number of C atoms (C12 – C24) are mostly met. They are dominated by acids with C16 and C18 (palmitic, stearic, oleic and linoleic acids), which are synthesized and destroyed in living cells by continuous joining or removal of two-carbon fragments [11].

The composition of milk fat is often criticized due to the high content of SFA, which, as stated in [12 – 14], is due to the risk of increasing the level of cholesterol in the blood, development of heart diseases, weight gain and

obesity. Conversely, it is believed that MUFA have a beneficial effect on human health due to their properties that reduce cholesterol content [15]. The most valuable are fatty acids of the ώ-3 and ώ-6 families, which are unique and efficient, have preventive and treatment properties, especially for preventing cardiovascular diseases [16-19].

Milk composition is mainly determined by the nutritional factors (type, quantity, and the quality of the fodder), as well as factors of animal origin, such as genetics and the stage of lactation [20-22]. A significant share of fatty acids' composition variability is determined genetically [23].

One of the main factors that influence the composition and properties of cow milk is the breed. Therefore, along with increasing milk production, particular attention is paid to improving milk quality and forming the high quality of the dairy products obtained from the milk of various breeds [24].

II. MATERIALS AND METHODS

The composition and process properties of milk in comparison were studied on motley-black and Alatau breeds of cows. The main farm for the research study was AO AIC Adal in the Almaty region of Kazakhstan. The experimental material consisted of 160 individual samples of milk from various breeds: 80 motley-black and 80 Alatau cows studied throughout the year (January 2018 through January 2019). The keeping, feeding, and milking conditions were the same. The cows at the dairy farm were kept loose. Milk samples were selected to provide an overall picture of milk composition, given the breed-related and seasonal conditions.

Physico-chemical characteristics of milk were examined at the laboratory of LLC Kazakh Research Institute of Livestock Breeding and Fodder Production in a high-performance, fully automatic milk analyzer MilkoScan FT+, Fossomatic FT+.

Samples were prepared, and fatty acid composition was determined in accordance with GOST 32915-2014 "Milk and Dairy Products. Determination of Fatty Acid Composition of the Fatty Phase Using Gas Chromatography". For studying fatty acid composition, a gas chromatograph GC Shimadzu-2010 Plus with a flame ionization detector, and a capillary column Agilent J&W Columns GP-Sii 88 for FAME with the dimensions of 100 m × 0.25 mm × 0.2 µl were used. The following gases were supplied to the detector from the gas flow regulator: nitrogen, hydrogen, and air; the maximum temperature of the detector was 260 0; temperature settings were as follows: 100 0C – 5 min, up to 210 0C – 8 min at the speed of 4 0C/min, up to 240 0C – 25 min at the speed of 10 0C/min; the volume of the injected sample was 1 µl. The samples' splitting flow was 1/40.

III. RESULTS AND DISCUSSION

Milk composition varies considerably depending on the breed of cows, stage of lactation, type of fodder, the season, and other factors. However, some relations among its components remain unchanged, and may be used as indicators of artificial changes in milk composition.

Milk productivity of the black-motley and Alatau cows over the 305 days of lactation is shown in Table 1.

In similar feeding and keeping conditions, the yield and the composition of the milk from the animals of the compared breeds were different.

The main indicators for determining the nutritional value of milk are the content of fat and protein, which are the main goals of breeding.

Table 1. Physico-chemical and microbiological characteristics of milk by season

Indicators	spring	summer	autumn	winter
Black-motley breed (n=80)				
Mass fraction of fat, %	3.75	3.72	3.71	3.63
Mass fraction of protein, %	3.34	3.32	3.29	3.25
Acidity, ^{0}T	16.9	16.8	17	17
Mass fraction of nonfat milk solids (NMS), %	8.48	8.56	8.81	8.69
Cleanliness group	I	I	I	I
Density, g/cm^3	1,029	1,028	1,028	1,027
Somatic cells content, thous. per 1 cm^3	377.1	307.7	372.5	362.5
Alatau breed (n=80)				
Mass fraction of fat, %	3.73	3.74	3.65	3.55
Mass fraction of protein, %	3.34	3.35	3.26	3.22
Acidity, ^{0}T	16.8	16.7	16.9	17
Mass fraction of nonfat milk solids (NMS), %	8.67	8.56	8.62	8.68
Cleanliness group	I	I	I	I
Milk density, g/cm^3	1,028	1,029	1,027	1,028
Somatic cells content, thous. per 1 cm^3	443.8	173.3	197.6	358.9

On average, the milk of black-motley cows contained 3.30 % of protein and 3.70 % of fat. At the same time, the milk of Alatau cows on average contained 3.29 % of protein and 3.67 % of fat. Significant differences between the breeds and the seasons were

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identified in the fat content in the milk of cows from the compared groups in the favor of the black-motley breed in the autumn and winter: by fat content (0.06 % and 0.08 %) and protein (0.03 %).

The most significant differences in the content of somatic cells in the milk of cows from the compared groups in favor of the Alatau breed were found in the spring (66.7 thous. per 1 cm3). In the summer, autumn and winter, the content of somatic cells was higher in the milk of black-motley cows, compared to Alatau cows (134.4 thous. cm3; 174.9 thous. cm3, and 3.6 thous. cm3).

Counting the number of somatic cells is one of the indicators of the state of the udder and milk quality. According to the norms of the European standards, cows are allowed to have 250 thous. somatic cells per 1 cm3, and according to the Technical Regulations of the Customs Union 033/2013 "On the Safety of Milk and Dairy Products" – 750 thous. per 1 cm3. If the number of somatic cells exceeds this value, milk quality is considered insufficient for high-quality dairy products due to the low content of casein, milk sugar, calcium, magnesium, and phosphorus [25].

The seasonal dynamics of mass fractions of the 16 main fatty acids in the milk fat are shown in Tables 2 and 3. Others are fatty acids not included in the list, the relative area of the peaks of which exceeded 0.1 %.

Table 2. The fatty acid composition in the milk in the spring and the summer

Fatty acid name	Period			
	Black-motley breed (n=40)		Alatau breed (n=40)	
	spring (n=20)	summer (n=20)	spring (n=20)	summer (n=20)
C4:0	3.65	3.18	3.66	3.36
C6:0	1.91	2.26	1.99	2.31
C8:0	1.16	1.42	1.6	1.44
C10:0	2.14	3.34	2.59	3.37
C10:1	0.28	0.28	0.34	0.28
C12:0	3.07	3.79	2.77	3.77
C14:0	11.43	11.98	10.97	11.34
C14:1*	1.24	1.4	1.12	1.42
C16:0	28.25	27.12	26.87	25.82
C16:1*	2.09	2.35	1.97	2.43
C18:0	10.31	9.93	10.94	10.59
C18:1*	24.85	24.67	26.93	25.51
C18:2*	3.51	2.72	2.66	2.73
C18:3*	1.3	0.8	0.97	0.73
C20:0	0.22	0.13	0.22	0.12
C22:0	0.08	0.07	0.06	0.06
Other	4.56	4.56	4.37	4.72
** The calculation is based on the sum of isomers*				

Table 3. The fatty acid composition in the milk in the autumn and the winter

Fatty acid name	Period			
	Black-motley breed (n=40)		Alatau breed (n=40)	
	autumn (n=20)	winter (n=20)	autumn (n=20)	winter (n=20)
C4:0	3.04	2.62	2.16	2.95

C6:0	2.46	2.11	1.56	2.30
C8:0	1.44	1.35	0.98	1.50
C10:0	3.16	2.96	2.31	2.56
C10:1	0.21	0.24	0.21	0.30
C12:0	3.41	3.13	2.72	3.20
C14:0	11.09	9.36	10.11	11.10
C14:1*	1.12	1.45	1.07	1.20
C16:0	26.31	26.78	27.94	25.40
C16:1*	2.09	2.05	2.05	2.14
C18:0	11.83	12.58	12.28	10.50
C18:1*	24.56	25.86	26.96	25.63
C18:2*	4.03	4.47	4.02	4.30
C18:3*	1.05	0.63	1.10	1.20
C20:0	0.12	0.19	0.16	0.20
C22:0	0.06	0.08	0.06	0.07
Other	4.01	4.14	4.32	4.37
** The calculation is based on the sum of isomers*				

As expected, SFA represented the most common class, followed by MUFA and PUFA. The most common fatty acids in both groups were C16:0, the sum of the isomers C18:1, C18:0 and C14:0. No statistical difference between the milk of these breeds in the concentrations of these compounds was observed. In addition, short- and medium-chain SFA, such as C4:0, C6:0, C8:0, C10:0, and C12:0 were present at the expected level. However, in the spring and summer, relatively high content of butyric acid C4:0 was noted in the milk of both breeds, which was characteristic of milk fat, and involved in the formation of the flavor of dairy products.

The amount of saturated fat is a very important indicator, as its unbalanced consumption is associated with an increased risk of cardiovascular diseases [26]. SFA such as palmitic, stearic, myristic, lauric, and other acids are mostly disposed of by the organism as an energy material. Palmitic acid is also the raw material for the biosynthesis of other saturated and monounsaturated acids.

Among MUFA, C18:1 isomers were the main components. Generally, the remaining monounsaturated fatty acids in the black-motley breed were 3.61 %; 4.03 %; 3.42 %; 3.74 %, and in the Alatau breed – 3.43 %; 4.14 %; 3.32 %; 3.64 % of the total amount of milk fat, and they were all significantly higher in the milk of the black-motley breed.

PUFA in the motley-black breed made 4.81 %; 3.52 %; 5.07 %; 5.1 %, and in the Alatau breed – 3.63 %; 3.46 %; 5.12 %; 5.06 % of the total amount of fatty acids. In both groups of milk, C18:2n-6 was the predominant compound.

The percentage of ώ -3 PUFA was higher in the samples from the black-motley breed (1.3 %; 0.8 % vs. 0.97 %; 0.73 %) in the spring and in the summer, compared to the Alatau breed; however, the percentage of ώ -3 PUFA in the autumn and winter periods in cows of the Alatau breed was 1.1 %; 1.2 % vs. 1.05 %; 0.63 % in the black-motley breed, whereas the percentage of ώ -6 PUFA (3.51 %; 4.47 % vs. 2.66 %; 4.30 %) in the spring and in the summer was higher in the cows of the black-motley breed, compared to the Alatau breed.

IV. CONCLUSION

The studies of the physicochemical and microbiological characteristics of the milk from the cows of various breeds between January 2018 and January 2019 have shown that the composition of milk from the cows of black-motley and Alatau breeds is considerably different; the differences also depend on the season.

The content of fat in the milk of cows of the black-motley breed in the spring was 3.75 %, which was the highest value, and the lowest fat content was observed in the winter in Alatau cows – 3.55 %. Significant differences also existed between the breeds in terms of somatic cells' content. In milk of the Alatau cows, in the spring, in the summer and in the autumn, the number of somatic cells reached 443.8, 173.3, and 197.6 thous. per 1 cm3, and in the milk of black-motley cows – 377.1, 307.7, 372.5 thous. per 1 cm3, respectively. Assessment of the fatty acid composition has revealed the most striking variations in the level of MUFA and PUFA, which was obviously determined by the introduction of green fodder into the diet of animals in these seasons.

To increase the concentration of the fat phase of milk and to improve its biological value, it is necessary to optimize the diets of high-yielding cows in the context of all nutrients, while monitoring the fat composition of the fodder, including the missing fatty acids.

REFERENCES

1. Lindmark Mansson H. "Composition of Swedish dairy milk 2001" Report Nr 7025-P (In Swedish), Swedish Dairy Association; 2003.
2. Fenelon M. A. and Guinee T. P. "The effect of milk fat on

Cheddar cheese yield and its prediction, using modifications of the van Slyke cheese yield formula", J. Dairy Sci. 82:2287–2299, 1999.
3. Esposito G., Masucci F., Napolitano F., Braghieri A., Romano R., Manzo N., and A. Di Francia. "Fatty acid and sensory profiles of Caciocavallo cheese as affected by management system", J. Dairy Sci. 97:1918–1928, 2014. https://doi.org/10.3168/jds.2013-7292.
4. Martini M., Salari F. and Altomonte I. "The macrostructure of milk lipids: The fat globules", Crit. Rev. Food Sci. Nutr. 56:1209– 1221, 2016. https://doi.org/10.1080/10408398.2012.758626.
5. Ivanov V. A., Tadzhiyev K. P. "Composition and technological quality of milk from Simmental and Simmental and Holstein cross cows", Agrarian education and science, N# 4, 2014.
6. Huppertz, T. Kelly A.L. , Fox P.F., Tamime A.Y. (Ed.) "Milk lipids – composition, origin and properties in dairy fats and related products", Blackwell Publishing, New Jersey, 2009.
7. Bilal G., Cue R. I., Mustafa A. F. and Hayes J. F. "Short communication: Genetic parameters of individual fatty acids in milk of Canadian Holsteins", J. Dairy Sci. 97:1150–1156, 2014. https://doi.org/10.3168/jds.2012-6508.
8. Loginova T.P. , Vorobyeva N.V. "Fat phase of milk - raw material of cows of different breeding in LLC "Plemzavod named after Lenin", Vestnik of Ulyanovsk state agricultural academy, 10.18286/1816-4501-2016-2-145-150, 2016.
9. Parodi P. "Milk fat in human nutrition", Australian J Dairy Technol, 59: 3_59, 2004.
10. Topnikova E.V., Gorshkova E.I., Merkulova M.I. "Investigation of the fatty acids composition of dairy butter", Cheese making and butter making, No. 3, 2013, pp. 47-49.
11. Guzeev Yu. V., Vynnychuk D.T. "Fatty acid composition of milk of different species of farm animals", Vestnik of Sumynational agrarian university, No. 5(29), , 2016 pp. 148-156.
12. Shingfield, K. J., M. Bonnet, and N. D. Scollan. "Recent developments in altering the fatty acid composition of ruminant-derived foods", Animal 7 (Suppl 1):132–162, 2013. https://doi.org/10.1017/S1751731112001681.
13. Tullo, E., E. Frigo, A. Rossoni, R. Finocchiaro, M. Serra, N. Rizzi, A. B. Samorè, F. Canavesi, M. G. Strillacci, R. T. M. M. Prinsen and A. Bagnato "Genetic parameters of fatty acids in Italian Brown Swiss and Holstein cows", Ital. J. Anim., Sci. 13:3208, 2014. https://doi.org/10.4081/ijas.2014.3208.
14. Pulina, G., A. H. D. Francesconi, B. Stefanon, A. Sevi, L. Calamari, N. Lacetera, V. Dell'Orto, F. Pilla, P. A. Marsan, M. Mele, F. Rossi, G. Bertoni, G. M. Crovetto, and B. Ronchi. "Sustainable ruminant production to help feed the planet", Ital. J. Anim. 2017. Sci. 16:140–171. https://doi.org/10.1080/1828051X.2016.1260500.
15. Schwingshackl, L., and G. Hoffmann "Monounsaturated fatty acids and risk of cardiovascular disease: Synopsis of the evidence available from systematic reviews and meta-analyses", Nutrients 4:1989–2007, 2012. https://doi.org/10.3390/nu4121989.
16. "Fats and fatty acids in human nutrition", Report of an expert consultation, FAO Food Nutr. Pap., No 91, 2010, pp.1–166.
17. Li C., Sun D., Zhang S., Wang S., Wu X., Zhang Q., Liu L., Li Y., Qiao L.. "Genome wide association study identifies 20 novel promising genes associated with milk fatty acid traits in Chinese Holstein", PLoS One, 9:e96186, 2014. https://doi.org/10.1371/journal.pone.0096186.
18. Zhang W., Zhang J., Cui L., Ma J., Chen C., Ai H., Xie X., Li L., Xiao S., Huang L., Ren J., Yang B. "Genetic architecture of fatty acid composition in the longissimusdorsi muscle revealed by genome-wide association studies on diverse pig populations", Genet. Sel. Evol. 48:5, 2016. https://doi.org/10.1186/s12711-016-0184-2.
19. Dobriyan E.I., Yurova E.A., Zhizhin N.A. "Functional milk products fortified with polyunsaturated fatty acids of the family omega-3 and omega-6", Dairyindustry, No.11, 2013, pp. 45-46.
20. Palmquist D.L. (2006) Milk Fat: Origin of Fatty Acids and Influence of Nutritional Factors Thereon. In: Fox P.F., McSweeney P.L.H. (eds) Advanced Dairy Chemistry Volume 2 Lipids. Springer, Boston, MA.
21. Soyeurt H., Gengler N. "Genetic variability of fatty acids in bovine milk", Biotechnol. Agron. Soc. Environ., No 12, 2008, pp. 203–210.
22. Kalač P., Samková E. "The effects of feeding various forages on fatty acid composition of bovine milk fat: A review", Czech J. Anim. Sci., 55: 521–537, 2010.
23. Stoop W.M., van Arendonk J.A.M., Heck J.M.L. v a n Valenberg H.J.F., Bove nhuis H. "Genetic parameters for major milk fatty acids and milk production traits of Dutch Holstein Friesians", J. Dairy, Sci., 91: 385–394, 2008.
24. Chokhataridi T.A. "The quality of milk of cows of different breeds on the «Ossetia» breeding farm", Proceedings of Gorsky State Agrarian University, No 22, 2010, pp. 77-79.
25. Abramova N.I., Serebrova I.S. "Effect of different milk production technology on milk yield of cows and somatic cell maintenance", Dairy Farming Journal, No 4 (20), 2015, pp. 7-12.
26. Perova N.V., Metel'skaya V.A., Sokolov E.I., Shchukina G.N., FominaV.M "Dietary fatty acids. Effects on the risk of cardiovascular diseases", Rational Pharmacother, 7(5), 2011, pp. 620-627.