Fatty acid profile of milk fat of different breeds of cows of the Voronezh region

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Abstract: The article examines the results of gas chromatographic analysis of the profile of fatty acids in milk fat from cows of different breeds. The changes in the fatty acid profile of milk fat of individual cows of red-and-white, black-and-white, Holstein and Jersey breeds bred in the Voronezh region are analyzed. Correlations of the fatty acid profile of milk fat of Jersey and Holstein cow breeds with a median profile, as well as a correlation between the content of fatty acids C10:0 and C12:0; C12:0 and C14:0 were found. The variability of the fatty acid profile in the milk of cows of different breeds and the presence of natural correlations in the ratios of fatty acids depending on the sum of genotypic and phenotypic factors were confirmed. Algorithms for identifying these factors using gas chromatographic data were proposed.

1 INTRODUCTION

As is known, the red-and-white breed of cows was bred in Russia by crossing Simmental cows with Holstein bulls of red-and-white color (genetically valuable servicing bulls from the USA and Canada were used for crossing). The breed was approved in the late 90s. Red-and-white cows have a pronounced dairy type, similar to the type of Holstein cattle. The milk of these cows is used for the production of butter and hard cheeses.

The black-and-white breed is a breed of cattle, primarily in the dairy sector of productivity. The black-and-white breed is related to the Dutch breed. It was bred in the USSR in the 1930s–1940s as a result of crossing local cattle, bred in various areas of the country, with black-and-white cattle of the East Friesian, black-and-white Swedish and other breeds, descended from the Dutch breed. The breed was approved in 1959, when animals with red colors were separated from it.

The Holstein breed is the most widespread breed of dairy cattle in the world, this breed of cows is considered one of the best in the world in terms of milk yield. The Holstein breed was created in the USA and Canada as a result of breeding the Dutch black-and-white breed of cows for productivity.

The Jersey breed belongs to small breeds of dairy cows. One of the oldest and most milk-rich cultivated breeds. Until recently unknown in Russia, the Jersey breed now ranks second in the world in terms of numbers after the Holstein breed, and its population is growing rapidly due to the fact that with smaller needs for living space, lower feed consumption (lower feeding costs, which make up 60% of the cost of milk), the Jersey breed shows a feed conversion rate that is 30% higher than the Holstein breed, and its milk is valued at least 20% higher than the milk of other breeds. The Jersey breed was bred in England

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on the island of Jersey by improving local Norman and British cattle and selecting them according to their fat content.

The article [Rudakov, 2017] shows that the fatty acid profile of cow's milk, as well as natural vegetable oils, varies in characteristic ranges not in a statistically random manner, but in compliance with biochemical correlations [Rudakov, 2005, 2018]. If the content of a particular fatty acid (FA) in the triglycerides of natural fat or oil that have not been fractionated, chemically and thermally affected, decreases or increases depending on the breed, nutrition, season and other climatic factors (for animal fats), varieties (for vegetable raw materials), etc., the content of another FA can increase or decrease symbatically (Soyeurt, 2006). Compliance with ranges within which the content of FA can vary, while maintaining natural correlations due to genotypic and phenotypic factors, is a sign of the naturality of this fat (Paszczyk, 2020).

The purpose of this work was to identify differences in the fatty acid profile of cow's milk fat in different breeds bred in the Central Black Earth Region based on chromatographic data, to confirm the presence of natural correlations, namely, to establish the most characteristic ratios for fatty acids typical in milk fat, which can serve to identify the naturality of milk fat (Hanuš, 2018).

2 EXPERIMENTAL PART

Milk was separated on a household separator "Rotor" at a temperature of 40-45 ° C, with the production of cream and skimmed milk. The ratio of the volume of cream and the volume of skimmed milk is 1:7.5. Milk fat was obtained by churning from cream cooled in a household refrigerator to 3 °C and then separating the fat phase from buttermilk by rinsing with ice water. The separation of butter into fat and serum was carried out according to GOST R 70238-2022 "Milk and dairy products. Method for identifying the profile of the fat phase and determining the mass fraction of milk fat." 50–70 g of product were placed in a glass with a capacity of 150 cm^3. A glass with a product sample was placed in a thermostat and kept at a temperature of (55±5) °C until the product was separated into fat and milk serum. The upper fat fraction was separated by carefully pouring it into another glass and filtered through a dry foldfilter at the same temperature (Wang, 2022).

The fatty acid profile of milk fat was obtained by the method described in GOST 32915-2014. "Milk and dairy products. Determination of the fatty acid profile of the fat phase by gas chromatography." Gas chromatograph Crystal 2000 M, capillary column SP-2560 (100 m; 0.25 mm), flame ionization detector.

3 RESULTS AND DISCUSSION

Tables 1 and 2 show the results of gas chromatographic determination of the fatty acid profile of milk fat from 9 cows of 4 breeds from farms in 3 locations in the Voronezh region during the transition from pasture to stall barn housing. To analyze the data in Table 1, we will use control charts (CC) [Rudakov, 2005, 2016, 2021]. We normalize the values of the selected controlled parameters and convert them into dimensionless values from 0 to 100% using the formula (1):

$$P_N=100(P_i–P_{min})/(P_{max}–P_{min}) \quad (1)$$

where P_i is an unnormalized parameter; P_{min} is the minimum permissible value of this parameter; P_{max} is the maximum permissible value of the parameter according to GOST 32261-2013 (percentage of the *i*-th fatty acid). The results of the analysis are visualized in MS Excel in the form of diagrams, where the normalized value of the FA content is plotted on the y-axis, and the x-axis, the category axis, indicates a number of 11 FAs, according to which fat is checked for compliance with GOST 32261-2013 (Fig.1). Jersey cow milk fat passed this test perfectly. All FAs were in the range from 0 to 100% according to normalized criteria.

Table 1: Fatty acid profile of cow's milk fat.

Fatty acid	Standard according to GOST 32261-2013	**1**		**2**		**3**		**4**		**5**
Butyric acid, C4:0	2.4-4.2	2.5	2.9	3.2	2.4	2.6	2.1	3.3	3.5	4.0
Caproic acid, C6:0	1.5-3.0	1.5	1.3	2.3	1.5	2.0	1.8	1.5	1.3	2.8
Caprylic acid, C8:0	1.0-2.0	0.8	0.9	1.4	1.1	1.3	1.4	0.7	1.0	1.5
Capric acid, C10:0	2.0-3.8	1.8	1.9	3.2	2.8	3.2	3.5	1.4	2.2	2.7
Decenic acid, C10:1	0.2-0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.2	0.2	0.4

Lauric acid, C12:0	2.0-4.4	2.3	2.6	3.7	3.6	4.2	4.7	1.7	1.9	3.1
Myristic acid, C14:0	8.0-13.0	9.5	9.8	11.5	12.0	13.0	13.1	6.8	8.0	11.0
Myristoleic acid, C14:1	0.6-1.5	1.3	2.0	1.3	1.7	1.3	1.9	0.7	1.1	1.4
Palmitic acid, C16:0	21.0-33.0	26.4	23.8	33.1	31.7	38.2	33.3	24.8	22.4	22.8
Palmitoleic acid, 16:1	1.5-2.4	2.2	1.9	1.9	1.9	2.5	2.1	2.2	2.0	1.7
Stearic acid, C18:0	8-13.5	10.8	11.8	9.0	10.2	5.8	6.9	11.7	13.2	13.4
Oleic acid, C18:1*	20-32	31.6	25.5	22.4	20.5	16.8	15.5	36.6	29.9	21.3
Linoleic acid, C18:2*	2.2-5.5	3.5	2.0	3.3	2.1	3.3	2.6	4.0	2.7	3.4
Linolenic acid, C18:3*	up to 1.5	1.0	0.8	0.4	0.3	1.0	0.9	0.9	0.8	0.6
Behenic acid, C22:0	up to 0.1	0.1	0.2	0.1	0.0	0.1	0.1	0.1	0.1	0.2
Arachidic acid, C20:0	up to 0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.4

Note: 1 – red-and-white breed (Yamnoye village); 2 – Holstein (Yamnoye village); 3 – Holstein (Novaya Usman settlement); 4 – black-and-white (Yamnoye village); 5 – Jersey breed (Liskinsky district)

Table 2: The ratio of the mass fractions of methyl esters of fatty acids.

The ratio of the mass fractions of methyl esters of fatty acids	GOST 32261-2013	1		2		3		4		5
Linoleic to myristic (C18:2/C14:0)	0.1-0.5	0.4	0.2	0.3	0.2	0.3	0.3	0.2	0.3	0.3
Oleic to myristic (C18:1/C14:0)	1.6-3.0	3.3	2.6	1.9	1.7	1.3	1.3	2.7	3.7	1.9
Palmitic (C16:0) to lauric (C16:0/C12:0)	5.8-14.5	11.5	9.1	8.9	8.8	9.1	9.1	9.6	11.8	7.4
Stearic acid to lauric acid (C18:0/C12:0)	1.9-5.9	4.7	4.5	2.4	2.8	1.4	1.4	5.8	6.9	4.3
Oleic and linolenic acid to lauric, myristic, palmitic and stearic ones (C18:1+C18:3)/(C12:0+C14:0+C16:0+C18:0)	0.4-0.7	0.7	0.5	0.4	0.4	0.3	0.3	0.5	0.7	0.4

In other cases, certain deviations from the norm are observed. Adulteration of milk fat is excluded, since the milk was collected from individual animals by the experimenters themselves. The fat phase was obtained from this milk under laboratory conditions. Thus, it can be concluded that GOST 32261-2013 provides a somewhat narrowed range of variation of FAs, which does not fully take into account the individual characteristics of the fatty acid profile of individual animals of different breeds, the season, climatic conditions and the diet of cows.

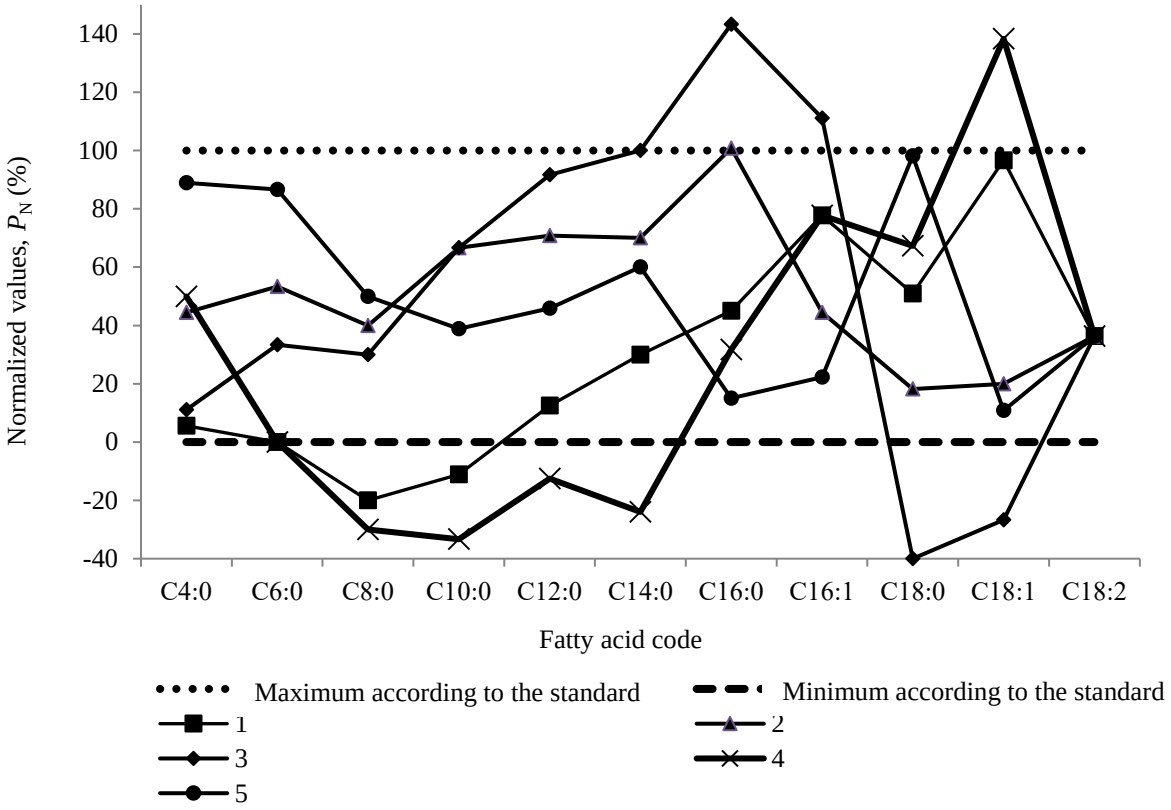

Figure 1: Fatty acid profile of milk fat of:
1 - red-and-white (Yamnoye village), 2 - Holstein (Yamnoye village), 3 - Holstein (Novaya Usman settlement), 4 - black-and-white (Yamnoye village) breeds of cows.

In GOST 32261-2013, the permissible range of fatty acid content was expanded for individual acids compared to GOST P52253-2004. Perhaps the standard should be revised again. If you look at the figures in Table 1, you can see that they are within the permissible limits of determination errors (for content less than 5% $\Delta=\pm0.4$, and for more than 5% $\Delta=\pm2.2$. That is, for the content, for example, 1.0%, values of 1.0±0.4 are acceptable (i.e. ±40 rel. %); and for 10.0 we have 10.0±2.2 (i.e. ±22 rel.%). It follows that, taking into account the errors, most of the indicators comply with the standards, but are close to the lower or upper limits of the CC. Absolute errors are most sensitive in normalized coordinates for minor fatty acids.

Apparently, a preliminary conclusion can be drawn from the diagrams in Fig. 1. Their profile depends on the genotypic factor, that is, on the breed of cows. Of course, phenotypic factors are superimposed on this factor – some differences in feed and livestock management [Rudakov, 2005], but if we assume that milk fat was produced with a similar diet, in the same region, in the autumn season, then the hypothesis about the influence of breed on the fatty acid profile of milk is viable. It is also possible to find similarities and differences in the fatty acid profile of milk of different breeds by comparing it with the "median" profile (average values in acceptable ranges - in the CC correspond to values of $P_N= 50$).

Let us check on our sample the observance of natural correlations identified in [Rudakov, 2002] based on statistical data for 50 samples of cow's milk fat.

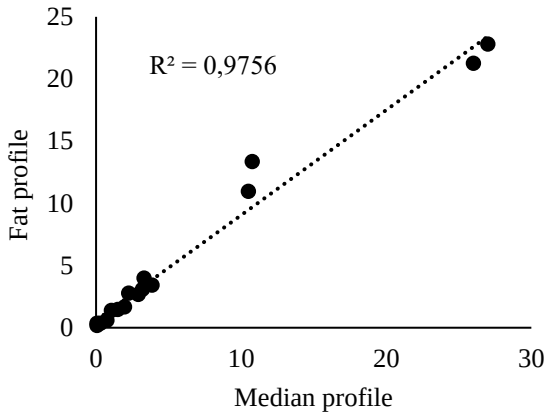

Figure 2: Correlation of the fatty acid profile of Jersey cow milk fat with the median profile.

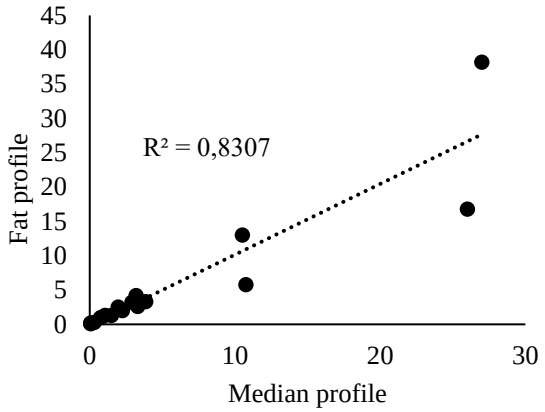

Figure 2: Correlation of the fatty acid profile of Holstein cow milk fat with the median profile.

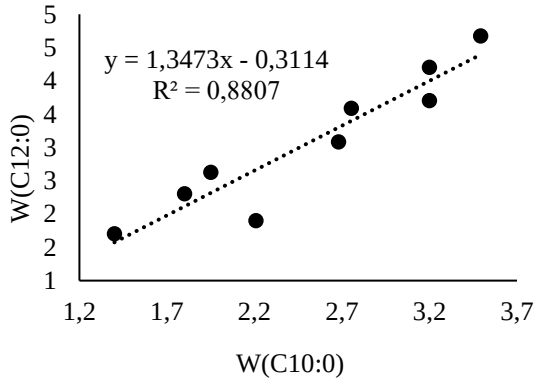

Figure 4: Correlation between C10:0 and C12:0 FA content, n=9.

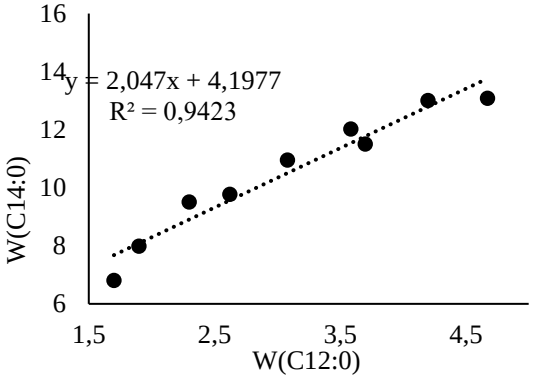

Figure 5: Correlation between C12:0 and C14:0 FA content, n=9.

As shown in [Rudakov, 2002], three acids are most sensitive to changes in the total FA profile: capric, lauric and myristic; the closest linear correlations are also observed between their content in milk fat. The content of palmitic, oleic and polyunsaturated acids slightly depends on the amount of other acids. Indeed, the ratios of the FAs C10:0 and C12:0, C12:0 and C14:0 closely correlate with each other (Fig. 8 and 9) even in such a seemingly not very representative sample (n=9). The data for other ratios (Table 2), provided by GOST 32261-2013, correspond to the permitted ranges, except for two indicators of one black-and-white cow, which, taking into account the maximum errors of chromatographic analysis, can be neglected, or one can think about standards that are acceptable for the average profile of fatty acids from large batches of milk. At the level of individual cows, deviations from the statistical data found with a confidence coefficient of P=0.95 are quite expected.

4 CONCLUSIONS

Thus, the study confirms the variability of the fatty acid profile in the milk of cows of different breeds and the presence of natural correlations in the ratios of fatty acids depending on the sum of genotypic and phenotypic factors. Algorithms for identifying these factors using gas chromatographic data were proposed.

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