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Composition and cheese suitability of milk from local Ukrainian cows and their crossbreedings with Montbeliarde breed

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Abstract. The aim of this work was to compare the qualitative composition of milk and its suitability for cheese processing at cows of local Ukrainian Red-Spotted breed (URS) and their crossbreeds with Montbeliarde (MO) breed. The research was conducted at commercial farm in the Vinnytsia region, Ukraine (48° 57′01″ n.l., 28° 47′09″ e.l). At farm, two groups of purebred and crossbred first lactation cows-analogues with a population of 20 heads in each were formed. The use of crossbreeding cows URS × Montbéliarde breed had a positive effect on the milk composition and cheese suitability. It was established that local purebred cows exceeded purebred counterparts in daily milk yield by 2.47 kg. When the content of fat, protein and lactose in milk was higher in crossbreed group by 0.19, 0.19 and 0.12%, respectively. In addition, crossbreed cows surpassed purebred counterparts for the energy value of 1 kg of milk and theoretically possible output of rennet cheese by 0.142 MJ and 0.61 kg. The duration of the coagulation phase of milk obtained from crossbred cows was shorter than that of purebred analogues by 1.54 minutes.

Key words: crossbreeding, local Ukrainian dairy breed, Montbeliarde, milk, suitability for cheese processing.

INTRODUCTION

Breeding of cattle is directed at improving the genetic value of animals and providing opportunities for future generations to produce milk in a more efficient way. Crossbreeding or interbreeding has a positive effect on the profitability of milk production, the reproduction, the health of dairy cows, and on the composition and properties of milk (Dezetter et al., 2015; Hazel et al., 2017). For this reason, crossbreeding programs in dairy cattle breeding have been widespread in recent decades in many countries. Thus, in the period from 2003 to 2014, in the United States, the number of cows obtained from crossbreeding increased from 0.5 to 4.5% (Hazel et al., 2017). In recent years, crossbreeding has been actively implemented in a number of other countries, such as India (Singh, 2016), New Zealand (Sneddon et al., 2016), Ireland

(Hazel et al., 2017) and Ukraine (Borshch et al., 2018). Holstein (HO) cattle are the most common milk breed in the world because of the ability to produce a large amount of milk.

El-Tarabany (2015) has detected that the crossbreeds of Brown Swiss and HO were less susceptible to metabolic disorders and to changes in their daily diet compared with pure breed HO. The results of the research conducted at the HO breed in different environmental conditions indicated a reduction in the productivity of the firstborn (Malchiodi et al., 2014; Hazel et al., 2017).

Hazel et al. (2017) reported that at the crossbreeds of the Montbeliarde and HO and Brown Swiss and HO breeds, milk contained more fat and protein compared with purebred HO. Blöttner et al. (2011) found no differences in the cast of fat and protein for the first three lactations at the crossbreeds of Brown Swiss and HO breeds compared to purebreeding HO.

One of the most important indicators that characterizes dairy raw materials, along with the content of fat, protein, and lactose, is the ability for processing into butter and cheese depending on the amino acid and fatty acid composition (Mapekula et al., 2011; Sun et al., 2014; Borshch et al., 2019).

The production of cheese is an important sector of milk processing, and the technological indicator of the cheese cast percentage (the amount of cheese obtained from a certain amount of processed milk expressed in percents) is the most important economic indicator for the dairy industry and, indirectly, for determining the price of milk (Cipolat-Gotet et al., 2013; Stocco et al., 2018; Amalfitano et al., 2020; El Jabri et al., 2020). The cheese industry is one of the most dynamic consumer segments with steady growth in production and consumption (Bankole et al., 2021; Mota et al., 2022; Sanchez et al., 2022). Cheese production is the most important technological parameter in the dairy industry in many countries, for example, in Italy, where almost 75% of milk is used for cheese production (Bittante et al., 2014). Thus, cheese output is an important feature of the Italian dairy industry (Bittante et al., 2013; Cecchinato et al., 2015).

The most popular dairy breeds in Ukraine are Ukrainian Black-Spotted (UBS) and Ukrainian Red-Spotted (URS). These breeds are common in all regions and climatic zones of the country. URS breed was created by crossing red-spotted local cattle with Simmental and Holstein breed. The main problems for the breed are the composition of milk and the duration of productive longevity (Borshch et al., 2021).

The aim of this work was to compare the qualitative composition of milk and its suitability for cheese processing at cows of local Ukrainian Red-Spotted breed and their crossbreeds with Montbeliarde breed.

MATERIAL AND METHODS

The research was conducted at commercial farm in the Vinnytsia region, Ukraine (48° 57′01″ n.l., 28° 47′09″ e.l). In farm holds the cows of the Ukrainian Red-Spotted (URS) breed and the first-generation of crossbred cows, which has been got thanks to the breeding with MO breed. At farm, two groups of purebred and crossbred first lactation cows-analogues with a population of 20 heads in each were formed. Indicator of average productivity is 22.70 ± 1.07 kg day^{-1}, days in milking - 92 ± 4 days. Dairy cows were kept loosely in brick barn for 100 heads. Parameters of placements (Length × Width × Height): 76×12×6 m. On the dairy farm, the cows were milked twice a day, from 06:00 to 08:00 and from 16:00 to 18:00. Accounting for the milk productivity

of experimental cows was carried out according to daily and monthly milk yields. Cows being milked in the milking parlour with a capacity of 2 × 6 on the installation 'Tandem' (Bratslav, Ukraine).

Cows fed total mixed ration (Table 1). Distribution of feed takes place twice a day (at 09.00 and 19.00 hours).

Samples of milk (500 mL) were selected during evening milking from each cow and stored without adding preservative in a refrigerator at a temperature of 4 °C for a period of 14 hours. Indicators of fat, protein, lactose content in milk, as well as density and freezing temperatures were determined in a milk analyzer (Milkotester Lactomat Rapid S, Bulgaria).

Table 1. Ingredients of diet fed to dairy cows

Item	Amount (kg)
Alfalfa hay	1
Barley straw	2
Corn silage	17.5
Bean haylage	10.5
Molasses	1.2
Compound feed[1]	6

Where: [1]Compound feed: 23% corn, 20% wheat, 18% barley, 15% peas, 5% oats, 5% wheat bran, 5% sunflower cake, 5% soybean meal, 2% feed phosphates, 1% NaCl, 1% premix.

Milk suitability for cheese was evaluated according to the rate of formation of a clot under the action of the rennet, and its quality - after the rennet-fermenting sample. The rate of formation of the clot was determined as follows: 20 mL of milk heated to 35 °C and 4 mL of a 0.03% solution of the rennet (Podpuszczka, Poland) were added to the sterile test tube. Prior to this, the rennet agent was dissolved in water. The contents were thoroughly mixed and placed in a water bath (MEMMERT WPE 45, Germany) at 35 °C. Time was fixed from the moment when milk was added to the rennet until the milk clotting. The end of the coagulation was considered the moment of formation of a dense clot that does not fall out of the tube with its careful overturning.

The rennet-fermenting test was carried out in such a sequence: 30 mL of milk was poured into the test tubes and then 1 mL of 0.5% solution of the rennet was added to each test tube, mixed well and placed in a water bath at a temperature of 38 °C for 12 hours, after which it was removed from the bath and examined. The assessment of the milk quality was carried out according to the characteristics of the formed clot. To class I the clots with the following features were assigned: a clot with a smooth surface, elastic to the touch, without eyes on a longitudinal section, floating in transparent whey; to the II class: a soft to touch clot, with single eyes (1–10), torn apart, but not scattered; to the III class: a clot with numerous eyes, spongy, soft to the touch, has come to the surface or instead of a clot a flatter mass has formed.

The net energy content (NEL) of milk was estimated by means of the following equation, derived from that proposed by the NRC (2001):

$$NEL = 0.0929 \times \text{fat, \%} + 0.0547 \times \text{protein, \%} + 0.0395 \times \text{lactose, \%} \quad (1)$$

where NEL is the gross energy of one kg of milk.

The NEL values obtained were converted to MJ kg^{-1}.

Predict the theoretical yield of rennet cheese was calculated according to Brito et al. (2002):

$$Y = 1.037 + 1.433 \times P_M + 1.71 \times F_M \quad (2)$$

where Y – theoretical yield of rennet cheese, kg 100 kg of milk; P_M – protein content of milk, g 100 g of milk; F_M – fat content of milk, g 100 g of milk.

All data are presented as the means ± standard error of the mean. Student's *t*-test was used to estimate statistical significance of the obtained values. Data were considered significant at $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$. These computations were performed using the STATISTICA software (Version 11.0, 2012).

RESULTS AND DISCUSSION

The productivity of crossbred cows was slightly inferior to the productivity of purebred analogues (Table 2). Thus, the average daily milk yield of URS × MO cows was 2.24 kg less than that of thoroughbred analogues. Instead, local cows significantly surpassed purebred analogues by the indicators of fat and protein in milk. The fat and protein content of the milk of crossbreed URS × MO cows was 0.19 and 0.19% higher than that of purebred cows. The content of milk in lactose of local cows was also higher than that of purebred analogues: by 0.12%. The amount of milk fat and protein affects the energy value of 1 kg of milk and theoretical yield of rennet cheese. According to the indices, the crossbreed's cows excelled the local analogues by 0.142 MJ and 0.61 kg, respectively.

Table 2. Composition and properties of milk at cows of different genotypes

Indicators	URS	URS × MO
Average daily milk yield, kg	23.44 ± 0.53	20.97 ± 0.46**
Mass fraction of fat, %	4.09 ± 0.05	4.28 ± 0.05*
Mass fraction of protein, %	3.15 ± 0.04	3.34 ± 0.05**
Mass fraction of lactose, %	4.34 ± 0.03	4.46 ± 0.04*
Energy value of 1 kg of milk, MJ	3.027 ± 0.015	3.169 ± 0.019***
Theoretical yield of rennet cheese, kg 100 kg of milk	12.28 ± 0.08	12.89 ± 0.13***

$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$ as compared with URS group. URS: Ukrainian Red-Spotted dairy breed; MO: Montbeliarde breed.

Crossbred cows often have lower daily milk yields than purebred cows (Dechow et al., 2007; Heins & Hansen, 2012; Hazel et al., 2014; Hazel et al., 2021). The results of our studies not coincide with the research results of Puppel et al. (2017), it is indicated that the crossbreeds of HO × MO breeds had a higher average daily productivity than purebred HO. However, Saha et al. (2017) report that the crossbreed first generation of HO × MO breed dominated the purebred HO cows by the indicators of the milk yield. In researches of Sneddon et al. (2016), they indicate that the heterosis effect after crossing the HO × Jersey breeds at New Zealand's farms had a positive effect on the cast of cheese and butter. At the same time, the productivity of such crossbreeds was lower than at purebred HO cows.

Numerous studies confirm the influence of breed on nutrient content in milk (Rafiq et al., 2016; Liang et al, 2018; Borshch et al., 2019). The breeds of cows are also notable for technological properties of milk, such as the duration of rennet coagulation, phases of gel creation, the size and number of fat balls, different constants of milk fat and the composition of its fractions (Fox et al., 2017). Such important indicators as protein content, rennet coagulation and quality of the rennet clot are determined primarily by breed and race of cows.

The duration of the coagulation phase of milk obtained from crossbred cows was shorter than that of purebred analogues by 1.54 minutes (Table 3). Indicators of the freezing point and milk density are of great importance in the technology of preparation of dairy products. In the studied samples of milk, these indicators corresponded to the requirements for raw materials for cheese-making. Established breed differences of the considered indicators have a character of tendency and are not statistically significant.

When creating a rennet-fermentation test, clots were classified as classes I or II. From the 20 investigated samples of milk of cows of URS breed 16 (80%) are classified as the I and 4 (20%) of the II class; 18 (90%) samples of milk of crossbred cows of URS × MO corresponded to the I and 2 (10%) to the II class.

Table 3. Characteristic of cheese suitability and physical-chemical properties of milk at cows of different genotypes

Indicators	URS	URS × MO
Coagulation time, min	12.88 ± 0.306	11.34 ± 0.326***
Freezing point, °C	-0.555 ± 0.0028	-0.551 ± 0.0033
Density, g cm^{-3}	1.0257 ± 0.002	1.0291 ± 0.004
Characteristic of a rennet clot according to the class, %:		
I	80	90
II	20	10

***$P < 0.001$ as compared with URS group. URS: Ukrainian Red-Spotted dairy breed; MO: Montbeliarde breed.

Our studies coincide with the data of Puppel et al. (2017), which indicate that the phase of milk coagulation at crossbreeds of the Polish Holstein with Brown Swiss and MO breeds was shorter than that of purebred Polish Holstein. Similar data were also obtained in studies by Saha et al. (2017) in which it was indicated that the duration of the coagulation phase at pure breed HO is longer than that of the HO × MO breeds.

CONCLUSIONS

The use of crossbreeding local Ukrainian cows (Ukrainian Red-and-Spotted) with Montbéliarde breed had a positive effect on the milk composition and cheese suitability. It has been established that in the milk of crossbred cows the mass fraction of fat, protein and lactose in the average essentially prevailed the pure-breed analogues (by 0.19; 0.19 and 0.12%). Besides crossbred cows dominated pure-breed analogues by the energy value of 1 kg of milk and theoretically possible output of rennet cheese by 0.142 MJ and 0.61 kg, respectively. The duration of the coagulation phase of milk obtained from crossbred cows was shorter than that of purebred analogues by 1.54 minutes. The daily milk yield in the group of purebred cows was 2.47 kg higher than in crossbreed cows.

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