Quality and safety of cow milk under conditions of ecological risk

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Abstract. Public health is a key factor in the development of the country and a special direction of state policy aimed at controlling the quality and safety of food products. Milk produced in regions with persistent multifactorial technogenic pollution of habitat objects, causing a high risk of raw materials contamination can adversely affect human health and cause long-term negative effects. The quality and safety of milk is a complex indicator, based on presence of proteins, fats, carbohydrates, vitamins, minerals and the absence of potentially dangerous substances, such as heavy metals, antibiotics and radionuclides. Produced in the conditions of megapolis, cow milk has shown good physico-chemical (freezing point – minus 0.533 ºС; acidity – 16.30 ºT; density – 28.4 ºА ) and technological (thermostability – 80.2 %) parameters and also good sanitary and hygienic properties (low bacterial contamination and somatic cells level, absence of pathogenic and opportunistic pathogenic microorganisms). No substances displacing technological processes during the production of dairy products (antibiotics), inhibitors and falsifiers were found in milk samples. Milk was characterized with minimal content of potentially hazardous substances (compounds of lead, cadmium and mercury). The detected 137Cs concentrations corresponded to the background level of the radionuclide content value. Cow milk produced in the environmental risks zone fully meets the requirements established by regulatory documents and can be used as a raw material for the production of high-quality and safe dairy products, including baby food.

1. Introduction
The population growth in megapolises stimulates an increase in dairy products demand, including those with a short realization period. The development of production and processing of milk near large cities becomes essential for the profitability of the dairy products manufacturing.

The processes of milk production are often carried out in conditions of high environmental risks or technogenic pollution. However, milk processing enterprises set high demands on the quality of raw milk used in the production of biologically complete and environmentally safe dairy products [1, 2].

The rational organization of the milk production process in order to ensure its quality and safety as well as the prevention of products contamination with potentially dangerous substances are tasks of a major importance.

The quality and safety of milk is a complex indicator based on the presence of proteins, fats, carbohydrates, vitamins, minerals and the absence of potentially dangerous substances, such as heavy metals, antibiotics and radionuclides.
Due to above-said, a comprehensive assessment of raw milk composition, its physico-chemical and technological parameters, sanitary and hygienic properties and the content of potentially hazardous substances are of practical and scientific importance for milk quality and safety improvement.

2. Materials and methods
The research was carried out on the cattle stock in the Educational and Production Animal-Breeding Complex of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy in Moscow.

By 01.05.2018 the herd consisted of 23 lactating cows with a yield of more than 6000 kg of milk per lactation with 3.87% fat content and 3.35% protein content.

The cows were kept using tied housing. Milking of cows was carried out twice a day on a milking machine GeaFarmTechnologies “WestfaliaMO”. The cows were fed feed according to the rations adopted on the farm, taking into account milk production, body weight and physiological state. The milk for the research was obtained from 10 Russian Black Pied cows having the second and third lactations. Milk yields from each cow were determined by the results of control milking (once a month). Selection and preparation of milk samples for physical and chemical studies were carried out in accordance with the requirements of State Standard 26809.1-2014 [3].

The study of the qualitative composition of milk was carried out in individual samples every month during lactation. The content of fat (%), protein (%), lactose (%), dry matter (%) and the freezing point (°C) of the average daily milk samples was measured using the Bentley 2000 device. The somatic cell count was calculated using the Somacount 300 device.

Acidity (ºT), density (ºA) and thermostability (%) of milk were determined in accordance with generally accepted procedures [4-6].

Sanitary and hygienic properties of raw milk were tested three times. Microbiological studies were carried out no later than 2 hours after sampling using 3M™ Petrifilm™ test plates, the temperature of the samples did not exceed +4 °C.

The residual amount of antibiotics was determined for mixed-herd milk with the use of rapid tests "4SENSOR KIT 060" in accordance with State Standard 32219-2013 [7].

The content of lead, cadmium and mercury compounds was determined in accordance with generally accepted regulatory and technical documentation [8, 9]. Cesium-137 content in a milk samples was determined triply on a Perkin-Elmer (USA) Wizard 2480 scintillation gamma spectrometer. The measurements were performed in the counting mode over the channels corresponding to the main line of the $^{137}$Cs γ-spectrum at the energy of 662 keV. Natural radiation was extracted automatically. The reliability of the results was analyzed using generally accepted methods of variation statistics, using Excel (MS Office).

3. Results and discussion
The average milk yield of a cow herd of Educational and Production Animal-Breeding Complex for 305 days of completed lactation was about 6000 kg of milk with fat content of 3.87%. Data on the level of milk production and the chemical composition of milk are given in Table 1.

| Table 1. Milk production of cows |
|---------------------------------|
| **Factor** | Minimum requirements for milk production of Russian Black Pied cows (2 - 3 lactation) | **Value (M±m)** |
|----------------|---------------------------------|----------------|
| Milk yield for 305 days lactation, kg | 3800 – 4200 | 5989.84±309.16 |
| Fat, % | 3.7 | 4.03±0.15 |
| Protein, % | 3.0 | 3.23±0.05 |
| Lactose, % | - | 4.66±0.21 |
| Dry matter, % | - | 12.89±0.13 |
Milk yield per lactation was 5989.84±309.16 kg, the amount of fat was 241.41±4.61 kg, and the amount of protein was 193.51±3.44 kg. The factors contributing to the high content of fat and protein in the cow milk include breeding and good nutrition of animals [10]. The fat content, which is an objective indicator of the nutritional value of milk, in the studied samples was 4.03±0.15% with fluctuations from 3.6 to 4.2%. The protein content in milk is of particular importance, since the cost of milk produced and the profitability of production depends on the value of this indicator. In the experimental group cow milk, the average protein content equaled 3.23±0.05%. Lactose determines the nutritional value of milk and plays a significant role in the formation of physical and chemical properties and affects the quality of dairy products. According to the research, it was obtained that the lactose content in milk varied between 4.45 and 4.96%. The dry matter content is an important and informative indicator for milk quality estimation, and the samples contained 12.89±0.13% of dry matter.

Complex of physical, chemical and technological properties of milk (Table 2) determines its grade, processing suitability and quality of dairy products, established by the requirements of Technical Regulations of the CU “On Safety of Milk and Dairy Products” (TR TS 033/2013) [11].

Table 2. Physics-chemical and technological properties of cow milk

| Indicator          | Normative documentation requirement | Value (M±m)       |
|--------------------|-------------------------------------|-------------------|
| Density, ºA        | 27                                  | 28.4±0.3          |
| Freezing point, ºC | -0.505                              | -0.533±0.022      |
| Acidity, ºT        | 16-21                               | 16.30±0.29        |
| Thermostability, % | 80                                  | 80.2±0.34         |

The density of milk, which is an objective indicator of naturalness, was within the norm provided by the requirements of TR TS 033/2013, and averaged 28.4±0.3 ºA. The temperature that determines the transition of milk from liquid to solid state depends on the content of lactose and mineral salts, the change in the concentration of which allows identifying possible falsification of raw milk. The freezing point of milk ranged from minus 0.497 to minus 0.559 ºC, which eliminates the possibility of falsification [11, 12]. The index of titratable acidity of milk was in the range of 16.03-16.58 ºT, which suggests a low level of raw materials bacterial contamination [10]. Thermostability, as a technological indicator, is determined by the dissolved salts equilibrium and the size of the casein molecules. The main reasons for thermostability reduction are changes in the salt balance or protein content and the high acidity of milk. Thermostability value satisfied the requirements for milk of the first thermostability group [4].

The complex of physical and chemical indicators and technological properties of cow milk meets the requirements of normative documents [4, 11, 12].

Development of the following microorganisms worsens the sanitary and hygienic indicators of raw milk quality and safety: sanitary-indicative (QMAFaNМ – quantity of mesophilic aerobic and facultative anaerobic microorganisms, CGB – coliform group of bacteria) microorganisms, spoilage microorganisms (yeast and mould) and pathogenic microorganisms (salmonella) [13]. The results of the sanitary and hygienic indicators evaluation are presented in Table 3.

The microorganisms content in the milk examined met the requirements established by TR TS 033/2013, and in accordance with State Standard 52054-2003 “Raw cow’s milk. Specifications” this milk is considered of the finest grade. The maximum value of the total bacterial contamination index in milk samples did not exceed the permissible value of 5·10⁵ CFU·cm⁻³; no potentially-pathogenic or pathogenic microorganisms (including Salmonella) were found [11, 14].

Counting the number of somatic cells gives an objective idea of udder health and changes in milk in case of mastitis. The somatic cells count in the examined milk samples was within the permissible norms
for the purchased milk of the highest grade, was not critical and met the requirements of Technical Regulations of the CU (TR TS 021/2011) “On Food Safety” [15].

Table 3. Sanitary and hygienic indicators of milk

| Indicator             | Normative documentation requirement | Value     |
|-----------------------|--------------------------------------|-----------|
| QMAFA\(N\)M, CFU·cm\(^{-3}\) | 5×10\(^5\)                            | 4.3×10\(^5\) |
| CGB, CFU·cm\(^{-3}\)     | Not allowed                          | Absent    |
| Salmonella, CFU·cm\(^{-3}\) | Not allowed                          | Absent    |
| Yeast, CFU·cm\(^{-3}\)   | -                                    | 3.1×10\(^3\) |
| Mould CFU·cm\(^{-3}\)    | -                                    | 1.4×10\(^2\) |
| Somatic cells count, thousand·cm\(^{-3}\) | 750                                 | 287±34    |

The use of Express tests “4SENSOR KIT 060” did not reveal any residual amount of antibiotics (levomycetin, penicillin, tetracycline group, streptomycin) in the mixed milk samples [11].

In order to detect possible inhibiting and falsifying substances in raw milk, the presence of melamine, formaldehyde and sodium bicarbonate was determined on the basis of infrared spectroscopy technology (Table 4).

Table 4. Inhibiting and falsifying substances content in milk, mg/kg

| Indicator                | Normative documentation                                      | Actual content |
|--------------------------|--------------------------------------------------------------|----------------|
| Melamine                 | TR TS 021/2011 “On Food Safety”                              | Absent         |
| Formaldehyde             | TR TS 033/2013 “On Safety of Milk and Dairy Products”        | Absent         |
| Sodium bicarbonate       | TR TS 033/2013 “On Safety of Milk and Dairy Products”        | Absent         |

Thus, the studies did not reveal any inhibiting and falsifying substances in the tested milk samples.

The results of heavy metals presence analysis are presented in the form of a diagram in Figure 1. For each of the toxicants, the actual content in the test samples was significantly less than the maximum permissible. It is easy to see that the content of mercury compounds in milk was very low and did not exceed 20% of the permitted value [1, 11].

![Figure 1. Heavy metal content in cow milk.](image-url)
Potentially hazardous contaminants of milk and dairy products subject to strict regulation include $^{137}$Cs. The results of the radionuclide content determination are shown in Table 5.

### Table 5. Radioactivity of $^{137}$Cs in milk samples

| Sample number | Radioactivity of $^{137}$Cs, Bq/l | Sample number | Radioactivity of $^{137}$Cs, Bq/l | Average radioactivity of $^{137}$Cs, Bq/l |
|---------------|----------------------------------|---------------|-----------------------------------|----------------------------------------|
| 1             | 0.23±0.20                        | 6             | 0.33±0.06                         |                                        |
| 2             | 0.15±0.12                        | 7             | 0.31±0.18                         |                                        |
| 3             | 0.32±0.08                        | 8             | 0.47±0.33                         | 0.31±0.04                              |
| 4             | 0.43±0.23                        | 9             | 0.31±0.24                         |                                        |
| 5             | 0.12±0.21                        | 10            | 0.44±0.07                         |                                        |

In all the milk samples the specific activities of $^{137}$Cs were extremely insignificant, ranged from 0.12 to 0.47 Bq/l on average and did not exceed the permissible level of radionuclide content established by TR TS 021/2011 “On Food Safety” which is equal to 100 Bq/l [15]. The detected $^{137}$Cs concentrations in milk (0.00-0.74 Bq/l for individual replications) correspond to the level of global radionuclide contamination after nuclear weapons tests in the second half of the 50s – early 60s of the XX century [16].

Comprehensive studies of milk samples have confirmed their full compliance with the requirements of regulatory documents on quality and safety indicators for both consumers and processors.

### 4. Conclusion

Cows of the Russian Black Pied breed kept in the Educational and Production Animal-Breeding Complex were characterized by a high level of milk production – 5989.84 kg for 305 days of lactation. The following average values of the chemical milk composition indicators were obtained: the fat content was 4.03%, the protein content was 3.23%, the lactose content was 4.66%, and the dry matter content was 12.89%. The milk had high physicochemical indicators (freezing temperature – minus 0.533 °C; acidity – 16.30 °T; density – 28.4 °A) and technological parameters (thermo-stability – 80.2%). As for the general bacterial contamination, the presence of yeast and mold milk complied with the normative documentation requirements. Neither coliform group bacteria nor Salmonella were detected. The average somatic cells count was 287 thousand·cm$^{-3}$, that is below the permissible level. No substances displacing technological processes during the production of dairy products (antibiotics) and also no inhibitors or falsifiers were found in milk samples. Despite the fact that milk was produced in the conditions of megapolis no excess of toxic elements (i.e. lead, cadmium and mercury compounds) level, was detected in the samples. The measured $^{137}$Cs isotope concentrations in milk correspond to the level of global radionuclide contamination. The safety properties of raw cow milk, such as heavy metals and radionuclides presence, have not been investigated before for milk produced in the Educational and Production Animal-Breeding Complex of the Russian State Agrarian University. The absence of previous research makes it impossible for us to compare the data with earlier results.

The cow milk produced in the ecological risks conditions fully met the requirements established by the normative documentation and was assigned to the highest grade. Milk produced in the conditions of a megapolis, characterized by high physicochemical and sanitary-hygienic properties, good technological indicators, extremely low content of potentially hazardous substances and radionuclides, can be used as raw material for the production of high-quality and safe dairy products, including baby food.

### References

[1] Ostroukhova V I and Ananeva T V 2018 The content of potentially dangerous substances in cow milk in the megapolis environment Mater. of the Int. Sci. and Practical Conf. Devoted to the
130th Anniversary of the birth of the outstanding scientist in the field of animal feeding, teacher and public figure pp. 194–199

[2] Ananeva T, Ostroukhova V, Vasilyeva E 2018 Electromagnetic exposure effect on microbiological characteristics of raw milk *17th Int. Sci. Conf., Eng. for Rural Development*, Proc. 17 90–96

[3] State Standard 26809.1-2014 “Milk and milk products. Acceptance regulations, methods of sampling and sample preparation for testing. Part 1. Milk, dairy, milk compound and milk-contained products” (in Russian).

[4] State Standard 25228-82 “Milk and cream. Method of determination of termostability on alcohol test (with change №1)” (in Russian).

[5] State Standard 3624-92 “Milk and milk products. Titrimetric methods of acidity determination (with change)” (in Russian).

[6] State Standard R 54758-2011 “Milk and milk products. Methods for determination of density” (in Russian).

[7] State Standard 32219-2013 “Milk and milk products. Immunoenzyme methods for determination of antibiotics (with change №1)” (in Russian).

[8] State Standard 30178-96 “Raw material and food-stuffs. Atomic absorption method for determination of toxic elements” (in Russian).

[9] State Standard R 54639-2011 “Foodstuffs and animal feeding stuffs. Determination of mercury by Zeeman atomic absorption spectrometry” (in Russian).

[10] “Order of the Russian Federation Ministry of Agriculture dated October 28, 2010 N 379 “On approval of the procedure and conditions for the valuation of breeding cattle in dairy and dairy-meat areas of productivity” (in Russian).

[11] Technical Regulations of the CU (TR TS 033/2013) “On Safety of Milk and Dairy Products” (Amended on December 20, 2017) (valid from July 15, 2018) (in Russian).

[12] Robinson K and Richard & Tamime A Y 2005 *Dairy Microbiology Handbook: The Microbiology of Milk and Milk Products, 3rd edition* 765

[13] State Standard R 52054-2003 (with changes № 1, 2) “Cow’s milk raw. Specifications” (in Russian).

[14] Technical Regulations of the CU (TR TS 021/2011) “On Food Safety” (in Russian).

[15] Lurie A A and Torshin S P 2008 Radioecological monitoring with the participation of university students *Reports of TAA* 280 210