INVESTIGATION OF THE INFLUENCE OF STORAGE CONDITIONS ON THE QUALITY AND PHYSICO-CHEMICAL PROPERTIES OF MILK

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Milk is one of the most essential and well-balanced biological systems in the human diet. However, its high water content and abundance of complete nutrients make it an extremely unstable system during storage. Violation of temperature regimes during transportation and storage, as well as an inappropriate choice of consumer packaging, activate undesirable microbiological and photochemical processes. This leads to premature spoilage of the product, loss of its native properties, and significant logistical losses. Therefore, a comprehensive study on the kinetics of chemical changes in milk quality indicators depending on environmental conditions is highly relevant.

The aim of the work is to investigate the dynamics and extent of the influence of temperature factors, storage duration, and packaging material type on the complex of organoleptic and physico-chemical properties of cow's milk to substantiate the optimal conditions for maintaining its quality.

The object of the study was the change in the quality and freshness of cow's milk during storage. Control of physico-chemical parameters was carried out using classical and instrumental methods of analytical chemistry: titratable acidity was determined by the titrimetric method of neutralization with NaOH solution (0.1 mol/dm³) using phenolphthalein indicator (expressed in degrees Turner, °T); active acidity (pH) was measured potentiometrically on a digital pH meter equipped with a glass electrode; the density of liquid milk was determined by lactodensimetry at a standard temperature of +20 °C. The experimental design simulated milk storage at room temperature (+20 °C) and under domestic refrigeration conditions (+4 °C) in various types of consumer packaging: glass bottles, PET bottles, and composite "Tetra Pak" cartons.

At the initial stage, the baseline chemical composition of whole milk was analyzed (Table 1), which allowed evaluating the integrity of the dry matter as a dispersed phase.

Milk density is a stable parameter, ranging from 1029 to 1031 kg/m³ for native samples, which fully complies with regulatory standards and indicates the absence of water adulteration.

Table 1. Chemical composition of whole cow's milk

Milk Component	Average Content, %	Variation Range, %	State in the System
Water	87.5	86.0–89.0	Dispersion medium
Total solids (dry matter)	12.5	11.0–14.0	Dispersed phase
– milk fat	3.8	2.8–6.0	Coarse emulsion (globules)
– proteins (casein, albumins)	3.3	2.8–4.0	Colloidal solution (micelles)
– lactose (milk sugar)	4.7	4.5–5.2	True molecular solution
– minerals (ash)	0.7	0.6–0.8	True and colloidal solution

It has been experimentally proven that the kinetics of changes in product acidity fundamentally depends on the storage temperature. Fresh milk samples had an initial titratable acidity of 17±1 °T and a pH value of 6.68. During storage at room temperature (+20 °C), following the completion of the brief bactericidal phase, rapid multiplication of mesophilic lactic acid bacteria was observed. These bacteria intensively ferment lactose into lactic acid.

It was established that after 12–18 hours of storage at room temperature, the titratable acidity reaches a critical limit (exceeding 21 °T), and after 24 hours, it exceeds 26 °T, accompanied by a drop in pH below 6.0. Such deep acidification causes the destruction of the stabilizing casein-calcium-phosphate complex and leads to irreversible acid coagulation of casein fraction proteins (curdling).

In the case of refrigerated storage (+4 °C), the vital activity of lactic acid bacteria was significantly suppressed, allowing the titratable acidity to remain within the normal range for 48–72 hours. However, long-term cold storage activates psychrotrophic microorganisms of the genus *Pseudomonas*, which secrete heat-stable proteolytic and lipolytic enzymes that deteriorate organoleptic characteristics (causing bitterness and rancid taste) without causing a sharp acidification of the system.

In parallel, the protective properties of packaging under continuous light exposure were evaluated. A comparative chemical analysis showed that multi-layer composite "Tetra Pak" packaging provides maximum protection of the lipid fraction against photochemical and free-radical oxidation. In transparent PET and glass containers, light exposure accelerates the destruction of vitamins and the hydrolysis of milk fat triglycerides, reducing the nutritional and biological value of milk.

A comprehensive evaluation of the analytical tools applied is summarized in Table 2.

Table 2. Comparative characteristics of milk physico-chemical control methods

Method of Analysis	Determined Parameter	Sample Analysis Time	Advantages of the Method	Limitations / Disadvantages
Titrimetry	Titratable acidity (°T)	5–7 min	High accuracy, low cost, simplicity	Subjectivity in fixing the equivalence point
Potentiometry	Active acidity (pH)	1–2 min	Objectivity, precision monitoring	Requirement for systematic calibration
Lactodensimetry	Density (kg/m³)	3–5 min	Rapidity, no consumables needed	Sensitivity to foaming and temperature

The kinetics of changes in milk physico-chemical parameters under the influence of temperature factors were studied, establishing that room temperature (+20 °C) is critical, as it causes titratable acidity to exceed regulatory limits (above 21 °T) after only 12–18 hours of storage. It was proven that composite opaque "Tetra Pak" packaging, compared to PET containers, minimizes destructive photochemical processes, reliably protecting protein micelles and lipids from light-induced oxidation. The necessity of combining potentiometric pH control with classical titration was substantiated for rapid and precise prediction of the residual shelf life of dairy products in retail networks.

References

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