

STUDY OF OPTIMIZATION AND MONITORING OF MOLD CHEESES RIPENING PROCESSES

Usmanaliyeva Ezoza Jalilovna

Tashkent Institute of Chemical Technology

master- M24-07OOTk,

Akramova Rano Ramizitdinovna

Tashkent Institute of Chemical Technology

professor, PhD

Annotation. Cheese ripening involving mold cultures, particularly *Penicillium roqueforti*, involves a complex of interrelated physicochemical and microbiological processes. This paper examines key parameters determining ripening dynamics, including temperature and humidity conditions, acidity, water activity, salt balance, as well as proteolysis and lipolysis parameters. Methods for quantitatively assessing these parameters, basic calculation formulas, and practical recommendations for monitoring are presented.

Key words: cheese ripening, mold cheeses, *Penicillium roqueforti*, ripening temperature, pH, water activity, salt balance, S/M, proteolysis, lipolysis, free fatty acids, soluble nitrogen, FAN, microbiological analysis, image analysis, mold growth, cheese texture, weight loss, cheesemaking, Food Chemistry

Introduction. The ripening process of mold-infected cheeses is a complex, multifactorial system involving interconnected mechanisms of mass and energy transfer, enzymatic transformations of macronutrients, and the controlled growth of specialized microflora, primarily *Penicillium roqueforti*. During ripening, a spatially heterogeneous product structure develops due to the diffusion of oxygen, moisture, and dissolved substances, as well as localized enzymatic activity.

From a scientific perspective, this process can be viewed as a combination of:

- diffusion phenomena (transfer of moisture, salt, and gases),
- biochemical reactions (proteolysis and lipolysis),
- microbiological processes (growth and metabolism of mold and associated microflora).

Proteolysis leads to the hydrolysis of casein fractions, producing peptides and free amino acids, which influence the texture and flavor of the product. Lipolysis, in

turn, is accompanied by the formation of free fatty acids, ketones, and secondary aromatic compounds, which form the characteristic aroma of blue cheeses. These processes are studied in detail within the fields of food chemistry and food microbiology.

Ripening management requires precise quantitative control of environmental parameters (temperature, relative humidity, water activity) and product composition (pH, salt content, moisture, degree of proteolysis and lipolysis). Even minor deviations in these parameters can lead to significant changes in the organoleptic properties and microbiological stability of cheese.

The primary objective of the study is to establish quantitative relationships between the measured parameters and the product's quality characteristics, including texture, aroma, flavor, and mold distribution.

From a scientific point of view, the consumption of blue cheeses is due to the fact that during the ripening process with the participation of *Penicillium roqueforti*, a complex of interconnected biochemical transformations is realized, including deep proteolysis of casein fractions with the formation of short peptides and free amino acids, characterized by increased bioavailability and potential physiological activity (including antihypertensive and antioxidant), as well as intensive lipolysis with the formation of free fatty acids, methyl ketones, lactones and other volatile compounds that determine not only the specific aroma of the product, but also help stimulate digestive processes; Moreover, cheeses of this type are a concentrated source of macro- and microelements (calcium, phosphorus, zinc), necessary for maintaining mineral metabolism and enzymatic activity of the body, and the metabolic products of mold cultures can have an indirect regulatory effect on the composition of the intestinal microbiota, which together allows us to consider such cheeses as a functional component of the diet within the framework of Food Chemistry and nutritionology, however, their consumption should be carried out taking into account the physiological limitations associated with the high mass fraction of table salt, significant energy density and the possible accumulation of biogenic amines during prolonged ripening.

Research Methods. To study the ripening processes of cheeses with internal mold caused by *Penicillium roqueforti*, a combination of physicochemical, microbiological, and instrumental analytical methods was used to quantitatively assess the dynamics of changes in product and environmental parameters. Temperature and humidity conditions were monitored using digital thermohygrometers: temperature was measured both in the ripening chamber and in the core of the samples, and relative humidity was continuously recorded. Acidity (pH) was determined potentiometrically using a food-grade pH meter, separately for the surface and core of the cheese.

The study included a comparative study of three groups of samples: Brie and Camembert cheeses, and a control sample (without mold culture or with different ripening conditions):

- Brie;
- Camembert;
- Camembert control cheese (local origin).

The ratio between groups was determined based on the principle of equal sampling, ensuring comparability of results for physicochemical and microbiological parameters. The primary objective was to identify differences in maturation dynamics, the degree of proteolysis and lipolysis, and the microbiological profile.

Particular attention was paid to monitoring pathogenic microflora, in particular *Salmonella* bacteria, which pose a potential food safety hazard. These microorganisms were detected using Rapoport's medium, which is used for selective enrichment of *Salmonella*.

The methodology included the following steps:

- sampling and homogenization of cheese samples;
- sample introduction into liquid Rapoport medium;
- incubation at elevated temperatures (usually 42°C), which promotes *Salmonella* growth while suppressing accompanying microflora;
- subsequent subculture onto differential diagnostic media to confirm the presence of the pathogen.

Comparative analysis allowed us to assess the impact of cheese type and ripening conditions on the risk of contamination, as well as confirm that adherence to technological parameters and sanitary standards is a key factor in preventing the development of pathogenic microflora.

Moisture content was determined gravimetrically by drying the samples to constant weight, followed by calculation of the dry matter content.

Table salt concentration was determined titrimetrically, and the salt-to-moisture ratio (S/M) was calculated, characterizing the availability of water for microbiological processes. If equipment was available, water activity (a_w) was additionally measured using a specialized analyzer.



a) Pathogenic microorganisms: *Simonella*



b) Method: *Salmonella* medium

The Rapoport method did not work; the *Salmonella* medium also did not work
Fig. 1. Determination of pathogenic microorganisms of the genus **Salmonella** using Rapoport medium.

The results were recorded on a "detected/not detected" basis for a given product weight (e.g., 25 g), which complies with microbiological food safety requirements.

Mold growth was assessed using digital image analysis: standardized photographs of cheese slices were processed using threshold segmentation to determine the proportion of the surface covered by mold. Microbiological analysis with colony-forming unit counting was performed at specific points throughout the experiment.

Proteolysis intensity was assessed using the soluble nitrogen ratio (SN/TN) or the free amino nitrogen content (FAN) spectrophotometrically, consistent with approaches used in food chemistry. The degree of lipolysis was determined by the free fatty acid content using titrimetric analysis.



Fig. 2. Determination using the following nutrient media:
Sabouraud, buffered peptone, and FB.

Additionally, changes in sample weight over time were recorded to assess moisture loss, and textural characteristics were analyzed using penetrometry or a basic texture profile. All measurements were performed during ripening, allowing for the generation of a dataset for subsequent analysis of the relationships between parameters and the quality characteristics of the finished product. The Brie and Camembert samples were characterized by a significantly higher degree of proteolysis compared to the control sample.

Table 1 presents a comparative assessment of the parameters in the cheese samples studied.

Table-1

Comparative analysis of the degree of proteolysis in cheese samples

Sample	Type of cheese	pH	humidity	proteolysis	lipolysis	growth	Salmonella

Brie	with mold	6.8-7.2	52	High	Medium	85	-
Camembert	with mold	6.5-7.0	50	High	High	90	-
Control	without mold	5.4-5.6	55	Low	Low	0	-

As demonstrated by the comparative analysis, blue cheeses are characterized by a higher pH, active proteolysis and lipolysis, and pronounced mold growth compared to the control sample, while maintaining microbiological safety.

Blue cheeses are the result of finely regulated and interconnected biochemical and microbiological processes mediated by specialized microflora, primarily *Penicillium roqueforti*. Their high nutritional and biological value is due to the profound transformation of proteins and lipids during ripening, resulting in the formation of easily digestible and physiologically active compounds. Comprehensive and scientifically based control of process parameters (temperature, humidity, pH, water activity, salt balance, and biochemical dynamics) ensures reproducible quality, microbiological safety, and targeted development of the product's organoleptic characteristics, as well as preserving and enhancing its functional properties, which are of significant interest in the context of food chemistry and modern nutrition science.

Conclusion. A comparative study of Brie and Camembert cheese samples and a control sample revealed that ripening processes involving mold microflora have a significant impact on the development of the physicochemical, microbiological, and organoleptic characteristics of the product. Moldy cheeses demonstrated higher pH values in the surface layers, intense proteolysis and lipolysis, and significant changes in texture and structure compared to the control sample. Enzymatic activity caused by mold growth promotes the accumulation of soluble nitrogen, free amino acids, and fatty acids, which is directly related to the formation of characteristic flavor and aroma. Furthermore, moisture, water activity, and salt content parameters confirm their key role in regulating the microbiological and biochemical ripening processes. Microbiological analysis revealed the absence of pathogenic microorganisms,

particularly *Salmonella*, in all samples studied, indicating compliance with sanitary and hygienic requirements and product safety.

Thus, the conducted study confirms that controlled ripening of blue cheeses ensures the formation of a product with high consumer and functional properties, and also ensures its safety while adhering to technological production parameters.

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