THE MODERN STATE OF MILK PROCESSING

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Annotatsiya. Maqolada sut xom-ashyosini qayta ishlash sanoatining rivojlanishi va oziq-ovqat mahsulotlari sifatiga qo‘yilayotgan talablarning kuchayishi sharoitida sut qayta ishlashning zamonaviy holati ko‘rib chiqilgan. Sutni qayta ishlash sohasidagi asosiy tendensiyalar — pasterizatsiya, ultrafiltratsiya, membrana texnologiyalari hamda ultra yuqori haroratda (UHT) qayta ishlash kabi yuqori texnologiyali usullarni joriy etish — tahlil qilingan. Innovatsion texnologiyalarning ozuqaviy qiymatini saqlash, mikrobiologik xavfsizligini oshirish va sut mahsulotlarini saqlash muddatini uzaytirishga ta’siri alohida yoritiladi. Soha uchun xos bo‘lgan muammolar — sutning tabiiylik darajasining pasayishi, qayta ishlangan sutdan sutdan foydalanish, stabilizatorlar qo‘llanishi va ishlab chiqarishning barcha bosqichlarida qat’iy nazorat zarurati to‘g‘risida ma’lumotlar kethltirib o‘tilgan. Xulosa sifatida, sutni qayta ishlash texnologiyalarining yanada rivojlanishi samaradorlik va xavfsizlikni tabiiy xususiyatlarni saqlagan holda uyg‘unlashtirishga qaratilishi kerakligi ta’kidlangan. Bu esa sut sanoatining raqobatbardoshligini oshirishning muhim omilidir.

Kalit so'zlar: sut, gidrodinamika, qayta ishlash, xavfsizlik, samaradorlik, texnologiya, joriy etish, samaradorlik, sifat, miqdor, ozuqaviylik, texnologiya, filtrasiya.

Аннотация. В статье рассматривается современное состояние производства и обработки молока в условиях развития молочной промышленности и ужесточения требований к качеству пищевых продуктов. Проанализированы ключевые тенденции в сфере переработки молока, включая внедрение высокотехнологичных методов пастеризации, ультрафильтрации, мембранных технологий и ультравысокой температурной обработки (UHT). Особое внимание уделено влиянию инновационных технологий на сохранение пищевой ценности, повышение микробиологической безопасности и увеличение срока хранения молочной продукции. Отмечаются проблемы, характерные для отрасли: снижение натуральности сырья, использование восстановленного молока, применение стабилизаторов и необходимость строгого контроля на всех этапах производства. В заключение подчеркивается, что дальнейшее развитие технологий обработки молока должно быть направлено на сочетание эффективности, безопасности

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и сохранение естественных свойств продукта, что является ключевым фактором повышения конкурентоспособности молочной отрасли.

Ключевые слова: молоко, гидродинамика, переработка, безопасность, эффективность, технология, внедрение, реализация, введение в действие, качество, количество, питательность, пищевая ценность, фильтрация.

Abstract. The article examines the current state of milk production and processing amid the development of the dairy industry and the tightening of food quality requirements. Key trends in milk processing are analyzed, including the introduction of high-tech methods of pasteurization, ultrafiltration, membrane technologies, and ultra-high temperature (UHT) treatment. Special attention is given to the impact of innovative technologies on preserving nutritional value, improving microbiological safety, and extending the shelf life of dairy products. The article highlights common challenges in the industry, such as the decline in raw milk naturalness, the use of reconstituted milk, the application of stabilizers, and the need for strict quality control at all production stages. The conclusion emphasizes that further development of milk processing technologies should aim to combine efficiency and safety while preserving the natural properties of the product, which is a key factor in improving the competitiveness of the dairy sector.

Key words: milk, hydrodynamics, processing, safety, efficiency, technology, implementation, implementation, commissioning, quality, quantity, nutrition, nutritional value, filtration.

Introduction.

The dairy industry is one of the key sectors of the food industry, supplying the population with essential food products—milk, fermented milk products, cheese, butter, and dry dairy ingredients. Modern milk processing is a high-tech field based on strict sanitary standards, automation, digital quality control, and an advanced scientific understanding of the biochemistry of milk. In the 21st century, the development of the dairy sector is driven by growing demand for functional foods, stricter safety requirements, and technologies that help produce more stable, nutritious, and diverse products.

Today, milk processing has long gone beyond traditional pasteurization and fermentation. The industry is rapidly adopting membrane technologies, UHT processing, automated quality control systems, robotics in packaging, and biotechnological solutions that improve raw material properties and enable new product categories. This article examines current trends, technologies, challenges, and prospects in modern milk processing.

The dairy industry directly depends on the quality of raw milk. In recent decades, many countries have invested in increasing dairy herd productivity, improving housing and feeding conditions, and enhancing hygiene. This leads to

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higher protein and fat content in milk, lower bacterial contamination, and more stable technological properties.

Today, raw milk usually arrives at processing plants already cooled, separated, and standardized. The growing share of small and medium-sized farms diversifies the market but complicates efforts to maintain consistent raw material quality.

Consumption Trends. Global demand for dairy products continues to increase due to:

- the rise of healthy eating habits;
- popularity of high-protein diets;
- consumer interest in functional foods (with probiotics, vitamins, etc.);
- expansion of the plant-based milk market, which—contrary to concerns—stimulates further innovation in the dairy sector.

Consumers are seeking safer, healthier, and more convenient dairy products. These expectations shape the technological development of the industry.

Milk Reception and Analysis. The first stage is raw milk intake at the processing plant. Modern facilities feature automated sampling and testing systems that instantly analyze:

- fat and protein content;
- presence of antibiotics;
- acidity;
- density;
- bacterial and somatic cell counts.

Infrared analyzers provide results within seconds, and digital monitoring systems automatically reject milk that does not meet standards.

Cooling and Storage. Cooling milk to +2…+4 °C is mandatory to slow bacterial growth and prevent spoilage. Although cooling is often done at the farm level, most processing plants are also equipped with additional storage and cooling tanks to stabilize raw material before processing.

Separation and Standardization. Separation divides milk into cream and skim milk. Horizontal and vertical separators with capacities ranging from a few thousand liters per hour to full-scale industrial units (25,000 L/h and more) are used.

Standardization adjusts the milk composition before further processing. Automated standardizers precisely mix cream and skim milk to ensure consistent fat content.

Pasteurization. Pasteurization is a key process for destroying pathogenic microorganisms. Modern methods include:

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❖ **low-temperature pasteurization (65–70 °C)** — used mainly for cheesemaking to preserve biological activity;
❖ **high-temperature pasteurization (72–78 °C)** — the most common industrial method;
❖ **HTST (85–90 °C for a few seconds)** — short-time high-temperature processing;
❖ **thermization**, a mild treatment to extend raw milk storage life before processing.

The general trend is toward minimal heat treatment while maintaining safety.

UHT Sterilization. UHT (Ultra-High Temperature) processing at 135–150 °C for 2–4 seconds destroys all microorganisms, including spores. It allows:
❖ long shelf life without refrigeration;
❖ minimal change in taste;
❖ improved product stability.

UHT processing is used for sterilized milk, cream, sauces, and infant formula.

Membrane Technologies. Membrane filtration is one of the most innovative directions. It includes:
❖ **ultrafiltration** for separating protein fractions;
❖ **microfiltration** for removing bacteria and spores;
❖ **nanofiltration** for removing dissolved substances;
❖ **reverse osmosis** for milk concentration.

Membrane methods can partially replace thermal pasteurization and improve milk properties for cheesemaking.

Homogenization. Homogenization breaks down fat globules, preventing cream separation and improving texture. High-pressure and ultrasonic homogenization are widely used. The process enhances digestibility and taste.

Fermentation. Modern fermentation relies on:
❖ probiotic cultures;
❖ mesophilic and thermophilic bacteria;
❖ biotechnological strains that enhance flavor and texture.

Fermentation forms the basis for yogurt, kefir, sour cream, and other products. The trend is toward reducing fermentation time and increasing culture stability.

Production of Major Dairy Product Categories. Produced as pasteurized, ultra-pasteurized, or sterilized milk. New methods help preserve nutrients and flavor through gentle temperatures and membrane filtration.

Fermented Dairy Products. Key trends include:
❖ growing demand for probiotics;
❖ expansion of functional product lines;

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- improved starter cultures.

Automated fermentation systems ensure consistent quality.

Cheese. Cheesemaking is one of the most complex processes. Modern developments include:

- ultrafiltration to increase yield;
- automated ripening chambers;
- robotic systems for flipping and washing cheeses.

Soft cheese and high-nutritional-value cheese categories are growing rapidly.

Butter and Cream. Traditional churning is being replaced by automated continuous butter-making systems. New technologies allow the production of butter with improved consistency and spreadability.

Dry Dairy Products. Milk is concentrated and dried using:

- spray dryers;
- fluidized-bed dryers;
- membrane concentration systems.

Dry dairy ingredients are widely used in sports nutrition, infant formula, and food manufacturing.

Automation and Digital Technologies. Digitalization is one of the leading trends in dairy processing. Innovations include:

- robots in packaging lines;
- automated CIP cleaning systems;
- online monitoring of pH, temperature, protein, and bacterial counts;
- digital twins of production lines.

Artificial intelligence optimizes recipes, reduces raw material loss, and predicts market demand.

Biotechnology. Biotechnology is becoming a core part of the industry. Innovations include:

- enzymes that improve coagulation;
- highly resistant starter cultures;
- probiotic combinations for functional products;
- lactose-reducing technologies.

Low- and lactose-free products are gaining popularity.

Sustainability and Energy Efficiency. Dairy plants aim to reduce their carbon footprint by:

- using heat exchangers for energy recovery;
- recycling water;
- adopting eco-friendly packaging;
- processing by-products such as whey.

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Whey, once considered waste, is now a valuable raw material for protein concentrates and isolates.

Packaging Innovations. Modern packaging includes:

- aseptic cartons and bottles;
- light- and oxygen-protective materials;
- biodegradable plastics;
- multifunctional resealable caps.

Packaging has become both a safety tool and a marketing instrument.

Challenges in Modern Milk Processing. Despite progress, the industry faces serious challenges.

Many regions face declining productivity, poor farm infrastructure, and insufficient farmer training.

Rising Production Costs. Costs are increasing for:

- energy;
- feed;
- equipment;
- transportation.

This pushes up retail prices.

Competition with Plant-Based Alternatives. The rising popularity of plant-based beverages forces dairy companies to innovate, improve quality, and diversify product lines.

Workforce Shortage. A lack of qualified food technologists and biotechnologists slows technological modernization.

Future Prospects of the Dairy Industry. The future of dairy products lies in personalized nutrition based on:

- genetic markers;
- individual dietary needs;
- functional additives.

Products will increasingly be tailored to specific consumer health profiles.

Expansion of Membrane Technology. Membrane processing will allow:

- improved protein concentration;
- higher raw material quality;
- reduced energy consumption.

It will become standard in cheesemaking and protein beverage production.

Artificial Intelligence and Robotics. AI will be used for:

- predicting raw milk quality;
- automatically adjusting processing parameters;
- safety monitoring;
- preventing production failures.

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Robots will take over labor-intensive tasks.

Sustainable Production and Bioeconomy. Milk by-products—whey, skim milk—will be used for:

- protein concentrates;
- bioactive substances;
- bioplastics;
- aquaculture feeds.

Conclusion. Modern milk processing is a high-tech industry that combines traditional methods with cutting-edge technologies. The growth of membrane filtration, automation, digitalization, biotechnology, and sustainability-oriented solutions makes dairy production more efficient and environmentally friendly. Demand is increasing for functional, healthy, and high-protein products, driving improvements in quality and product diversity.

Despite existing challenges—raw material shortages, rising costs, and workforce deficits—the industry continues to develop. In the coming years, we can expect further modernization, greater use of artificial intelligence, expanded functional product lines, and greener production practices.

Thus, modern milk processing is undergoing dynamic technological transformation and adapting to new societal and market demands, making it one of the most innovative sectors of the 21st-century food industry.

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