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TECHNOLOGICAL SOLUTIONS FOR THE SAFE AND WASTE-FREE PRODUCTION PROCESS OF DAIRY PRODUCTS (MILK WHEY)

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Abstract: This article focuses on ensuring safe, high-quality, and waste-free dairy production within the dairy industry. The paper discusses the optimization of production processes, waste reduction and recycling technologies, adherence to sanitary and hygienic rules for quality product production, as well as laboratory and certification measures to ensure quality and safety, with a particular emphasis on dairy whey.

Keywords: Dairy industry, whey, food safety, waste reduction, cooling and storage, lactose, digital monitoring.

INTRODUCTION.

Dairy products play a crucial role in the food consumption of the population. Their safety and quality not only affect consumer health but also have a significant impact on national food security and export potential. At the same time, the dairy industry negatively affects the environment through wastewater discharge, organic waste production, and energy consumption. Therefore, implementing technological solutions based on the principles of safe and waste-free production is a priority task.

Many studies link the consumption of dairy products with lower blood pressure. Scientists attribute this positive effect to inhibitors from the family of bioactive peptides (AGF). In milk proteins, lactocinins primarily perform this function.

The byproduct of dairy processing—whey—is distinguished by its unique properties that provide several beneficial characteristics. It helps reduce excess weight and supports weight loss efforts.

Increased protein intake contributes to fat reduction through various processes: suppressing appetite, accelerating metabolism, and preserving muscle mass during dieting. This makes it possible to consume dairy products daily, even while following strict diets, helping to overcome hunger.

Whey replenishes the body's supply of energy, amino acids, vitamins, and minerals. The product is obtained from sour milk (curdled milk). It can be purchased ready-made or prepared at home by following certain rules:

- Pour soured milk into a pot and heat over fire. It's recommended to use a water bath method to prevent boiling the liquid, as otherwise, the curds will become hard, and the taste of separated whey will be spoiled.
- Remove the pot from the heat when the curd mass is still soft. Then pass the mixture through a strainer lined with cloth, allowing the whey to drain out.

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- From one liter of sour milk, you obtain little cheese but plenty of whey, which can easily be added to your diet. Drink it before meals in the first half of the day. For immune support and detoxification, drink one glass on an empty stomach every day. Whey has a mild laxative effect, so it's advisable to introduce it gradually into your diet and avoid important activities outside the house until you're accustomed to it.

Literature Review.

Extensive research has been conducted on milk whey by numerous scholars. Notably, Louis Pasteur (1822–1895) investigated microbial activity in milk whey and established the foundation for the pasteurization process. Similarly, Patrick Fox conducted in-depth studies on whey proteins and their diverse functional applications within the food industry.

Research by dietitians and nutritionists demonstrates that whey consumption is far more than a convenient method of incorporating essential amino acids into one's diet. This "miracle drink" offers a wide array of health benefits, some of which are yet to be fully elucidated. It is well-established that whey enhances physical endurance, accelerates post-workout recovery, normalizes gastrointestinal functions, increases satiety, and assists in preventing overeating.

Whey products can be consumed daily, even under strict dietary restrictions, due to their low-calorie content and effectiveness in suppressing hunger. It replenishes the body with essential energy, amino acids, vitamins, and minerals. According to experts, daily consumption of a glass of whey can significantly boost the immune system and enhance overall physical well-being within a few weeks. Ultimately, milk whey is not merely a recyclable byproduct; it is a natural substance possessing numerous properties highly beneficial to human health.

Research Methodology

A range of modern technological methods and solutions are employed to transform whey into high-value products:

•Membrane Technologies (Ultrafiltration, Nanofiltration, Reverse Osmosis): These techniques are used to extract whey protein concentrates (WPC), lactose, and minerals from whey. While ultrafiltration is utilized for protein separation, nanofiltration enables the concentration of lactose.

•Evaporation and Drying: Lactose and whey protein concentrates are converted into powder form through evaporation and spray drying. This process significantly facilitates storage and transportation.

•Fermentation: By fermenting the lactose found in whey, it is possible to produce ethanol, lactic acid, and various other biochemical products.

•Chromatographic Separation: This method is applied to isolate high-value biocomponents from whey, such as lactoferrin and lactoglobulin.

Whey-Based Products and Their Applications

The following products are derived from processed whey:

•Whey Protein Concentrates (WPC) and Isolates (WPI): Widely used in sports supplements, infant formulas, dietary products, bakery goods, and beverages.

•Lactose: Utilized in the food industry, as a tablet filler in pharmaceuticals, and in infant nutrition.

•Whey Beverages: These can be integrated into natural drinks and juices to enhance their overall nutritional value.

•Animal Feed: Used as a high-protein nutritional supplement for livestock.

•Cosmetics and Pharmaceuticals: Certain whey components are also utilized in the formulation of cosmetic products and medicinal drugs.

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Process Optimization and Risk Management

The methodology accounts for several critical factors, including raw material quality, sanitation and hygiene, cooling and transport logistics, and microbiological risks during processing. It also addresses waste management, including wash water, pH-altered milk, solid organic waste (residual fats), and plastic containers.

Optimization is achieved by developing a process map that integrates HACCP (Hazard Analysis and Critical Control Points) at every stage, along with smart technological sensing (monitoring temperature, pH, and various biomarkers) and waste stream tracking. Furthermore, the research employs laboratory analytics (microbiological and chemical), energy audits, Life Cycle Assessment (LCA), and pilot production models to ensure efficiency and sustainability.

Discussion and Results.

1. Improvement of Raw Material Quality Control and Delivery System

- Installing automated devices at milk reception points to measure parameters like temperature, pH, lactose levels, fat content, and total microorganisms.
- Establishing a traceability system based on QR codes where each batch of raw material is linked to all relevant information from the supplier to receipt.
- Making mandatory compliance with transport conditions corresponding to product standards (refrigeration range of 0–4°C).

2. Aseptic Processing and Minimization of Thermal Impact

- Improving and optimizing aseptic conditions both during and after pasteurization.
- Reducing microbial load and maintaining product quality.
- Utilizing energy-efficient cooling systems such as closed-loop chillers and combined heating-cooling units.

3. Digital Monitoring and Automated Management Systems

- Using platforms for collecting and analyzing data; generating predictions based on analyses.
- Automating HACCP checkpoints and streamlining certification processes based on gathered data.

4. Reduction and Recycling of Wastes

- Separating milk residues and rinse waters: extracting organic matter for biogas production through anaerobic fermentation (reusing energy).
- Reprocessing fats and solid wastes through special filtering and drying techniques for animal feed or compost.
- Introducing water purification systems to recycle water and minimize wastewater.
- Transitioning to recyclable and compostable packaging materials to reduce plastic usage.

5. Energy Efficiency and 'Green' Solutions

- Implementing heat recovery systems, reusing thermal energy generated during pasteurization and cooling processes.
- Conducting systematic energy monitoring and auditing.

Operational Measures for Ensuring Quality and Safety

- Complete implementation of the HACCP system: identifying hazards, establishing control points, conducting monitoring, and documenting processes.
- Accrediting laboratories according to ISO standards.
- Providing training for workers regarding sanitary-hygiene regulations, equipping them with necessary personal protection gear, and ensuring correct workflow organization.

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- Regularly introducing technical systems for equipment maintenance.

Economic and Ecological Efficiency Analysis

-Initiating waste recycling and energy efficiency programs requires initial investment, but reduces expenses in the mid- to long-term, decreases waste disposal costs, and provides additional energy resources (biogas).

-Expanding market share and earning extra income from premium products (organic, low-emulsion, long shelf-life aseptically packaged goods) by meeting export quality demands.

Implementation Steps

- Engaging private-public partnerships for financing and technical assistance.
- Developing educational programs and certifications: organizing trainings for staff and managers on technological and sanitary-hygienic requirements.

-Adopting European technologies for producing dairy products, specifically membrane production methods.

-Setting up packaging and waste recycling facilities supported by targeted grants and tax incentives.

-Openly announcing results and monitoring data to build trust among consumers and ensure transparency.

Conclusion.

The dairy industry holds great significance not only in providing the population with high-quality food products but also in terms of ensuring environmental sustainability and efficient resource utilization. The technological solutions presented in this article, including the optimization of production processes, digital monitoring, aseptic technologies, and especially the recycling of whey, contribute to transforming the dairy sector into a safe and waste-free system.

The rich composition and health benefits of whey further enhance interest in this product. Through the adoption of advanced technologies suited to local conditions, government support, and strengthened scientific collaboration, there exists an opportunity to raise Uzbekistan’s dairy industry to higher levels, ensuring product safety and environmental conservation.

Producing dairy products safely and sustainably involves substantial investment and requires coordinated efforts in science, technology, and economics. To achieve this goal, digital monitoring throughout all stages of production, from raw materials to end-consumption, along with aseptic and energy-efficient technologies, should be introduced. Additionally, adopting circular economy approaches for waste recycling is essential. These solutions not only guarantee public health but also boost production efficiency, reduce environmental burdens, prevent water pollution, and improve economic viability.

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