Scientific Papers. Series D. Animal Science. Vol. LXIX, No. 1, 2026
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

FROM WASTE TO RESOURCE: MODERN APPROACHES TO WHEY UTILIZATION IN THE FOOD INDUSTRY

Mihaila ZLATAROVA, Nikolina NAYDENOVA

Trakia University, Faculty of Agriculture, Student`s camp, Stara Zagora, Bulgaria

Corresponding author email: mihaila.zlatarova@trakia-uni.bg

Abstract

This review examines current approaches to whey valorization in the food industry, focusing on its transformation from a dairy by-product into a source of proteins, minerals, and bioactive compounds for functional foods and beverages. The paper summarizes contemporary scientific approaches to its use – from the development of functional drinks and protein concentrates to biotechnological and ecological solutions for managing waste streams, thereby closing the resource loop and supporting the circular economy. Emphasis is placed on the role of whey as a key element in the sustainable development of the dairy industry, as well as the opportunities for its effective utilization. Efficient whey valorization increases the profitability of enterprises, reduces environmental impacts, and leads to the creation of new health-promoting products that contribute to improved human health and quality of life.

Key words: *bioactive compounds, circular economy, dairy by-products, functional beverages, whey valorization.*

INTRODUCTION

Dairy products are indispensable foods that have an important place in human nutrition due to their rich composition, which includes a wide range of nutrients and biologically active substances. During cheese manufacture, whey is generated as the main liquid by-product remaining after milk coagulation and curd separation (Rocha-Mendoza et al., 2021; Tsermoula et al., 2021). During the production of one kilogram of cheese, 9 to 10 liters are separated as whey (Rocha-Mendoza et al., 2021).

According to Kim et al. (2022), global cheese production is expected to increase by up to 14% by 2029, which will lead to an increase in whey volumes. This relationship is direct because whey represents the major liquid fraction separated during cheese manufacture, accounting for approximately 85-90% of the initial milk volume depending on the type of cheese and processing conditions. The quantities are projected to reach approximately 203-241 million tons by 2030, with an anticipated annual growth of up to 2%. In 2020, Europe produced nearly 148 million tons of milk, and almost 50% of this milk was used for cheese production, where about 90% of the milk volume is separated as whey, resulting in approximately 55 million tons of liquid whey. This makes whey the largest-volume waste stream in the dairy industry (Švikruhová et al., 2022). Therefore, the increasing availability of whey is not only an environmental challenge but also a technological and economic opportunity for the dairy sector.

Of this amount, 13 million tons represent the annual surplus of cheese whey, while 40 million tons are generated solely within the European Union (Zotta et al., 2020; Barba, 2021).

The challenge associated with the effective utilization of whey is characteristic of all countries with developed dairy industries. With the advancement of modern technologies and the growing awareness of whey's beneficial properties, its application in the food industry is expanding, transforming it into a significant component of modern food production. In industrialized countries, between 70% and 90% of whey is already processed for food purposes. Nevertheless, the issue of its full and rational utilization has not yet been completely resolved at the global level. Therefore, research aimed at developing new products and technologies for whey utilization is becoming particularly relevant (Blais et al., 2022; Vera-Santander et al., 2024).

Unprocessed whey contains significant amounts of organic substances, mainly lactose and proteins, which, when discharged into water bodies, increase biochemical oxygen demand

and may lead to serious ecological imbalance (Mirzakulova et al., 2025).

It is considered one of the most polluting by-products of the food industry, as the oxidation of the organic compounds contained in 1 liter of whey requires between 34 and 39.2 grams of oxygen. Each ton of whey discharged into wastewater pollutes water bodies to a degree equivalent to approximately 100 m³ of domestic wastewater. Whey discharged into wastewater leads to reduced levels of dissolved oxygen and toxicity issues, which alter the physicochemical properties of aquatic ecosystems (Zandona et al., 2021). It is regarded as industrial waste by enterprises and is directed to wastewater treatment plants (Tsermoula et al., 2021). The separated whey, as a secondary product, must undergo appropriate treatment methods before being discharged into the ocean, which represents an additional cost for the dairy processing industry.

The main pathways of whey valorization, from its generation during cheese manufacture to its application in food systems and circular-economy processes, are schematically presented in Figure 1.

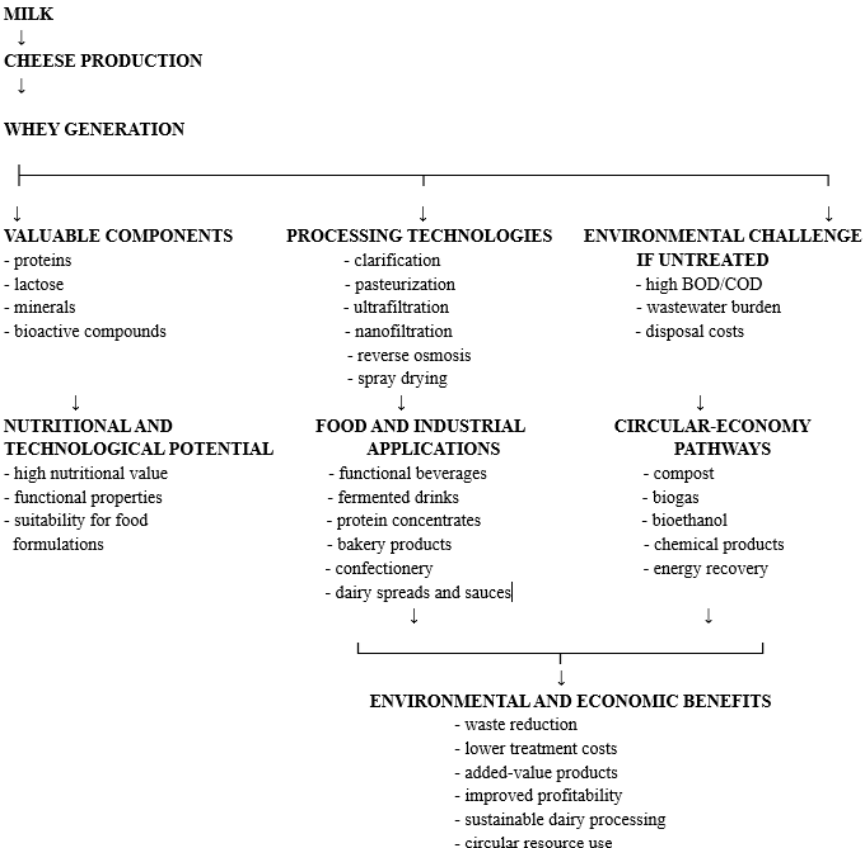

Figure 1. General pathways for whey valorization in the food industry and circular economy

Scientific research emphasizes the urgent need for sustainable solutions that would enable the processing of up to 90% of whey into valuable products (Mirzakulova et al., 2025).

The introduction of efficient technologies for whey valorization not only reduces pollutant emissions into the environment but also supports the development of sustainable, zero-waste production systems. This approach increases the efficiency and profitability of the dairy industry by transforming whey into a source of high value-added food products and functional beverages (Graikini et al., 2024).

New production systems must be sustainable and minimize the environmental impact of the dairy industry. In addition, the industry must

comply with standards for waste disposal, treatment, and sanitation in order to reduce environmental pressure. Management practices must remain sustainable, productive, and economically efficient (Roufou et al., 2021). In this context, whey treatment and recovery are of key importance for its valorization and for reducing environmental burden.

Despite the growing body of literature on whey processing, many studies focus separately on membrane treatment, beverage development, or environmental management. A more integrated perspective linking whey composition, purification technologies, food applications, and circular-economy pathways is still needed. Therefore, the aim of this review is to synthesize recent research on whey valorization in the food industry, with emphasis on functional beverages, product development opportunities, and sustainable strategies for reducing dairy waste.

COMPOSITION AND PROPERTIES OF WHEY

The use of whey as a secondary dairy product date back several millennia and is historically associated with traditional cheese-making practices. In appearance, it is a cloudy liquid with a sweet-sour taste and a mild characteristic aroma. The composition and properties of whey are influenced by the type of milk, the feeding regime of the animals, the milk processing technology used, and other environmental factors (Tsermoula et al., 2021; Sinđić & Pajic, 2025). Two types of whey are known - sweet and acid - depending on the production method and the coagulation process. Sweet whey is typically obtained during rennet coagulation in cheese production, whereas acid whey results from acid coagulation processes such as the manufacture of fresh cheeses or strained fermented dairy products. These two whey types differ in pH, mineral balance, and potential applications, which is important when selecting appropriate valorization strategies.

Fresh, unprocessed cow's milk whey contains approximately 93% water, and its main component is lactose, which accounts for up to 70-75% of the dry matter; about 14% consists of protein compounds, around 6% of milk fat, and the remainder is represented by minerals. The predominant minerals are calcium, phosphorus, magnesium, potassium, sodium, and zinc. The vitamins present are mainly from the B group. Bioactive peptides in whey are an important indicator for improving immune function and provide an antioxidant effect on human health (Pașca et al., 2024). These compositional characteristics determine the technological and nutritional value of whey and explain its suitability for incorporation into functional beverages, protein-enriched foods, fermented products, and bio-based ingredients.

The organoleptic characteristics of whey are defined by its appearance, color, odor, and taste (Larionov et al., 2020). In terms of appearance and color, it is a homogeneous liquid without foreign impurities, with a pale greenish hue. The presence of protein sediment may be observed. It has a characteristic whey taste and aroma. One of the most important and initial processes before whey is used in products is clarification by centrifugal force. The next step is pasteurization, which is the most important process from a microbiological standpoint.

PURIFICATION TECHNOLOGIES

More than 90% of whey is recycled into valuable products in countries with advanced processing systems that set the standard for sustainable practices in the dairy industry (Costa et al., 2021). The use of reverse osmosis and ultrafiltration membranes can remove up to 100% of the biological and chemical oxygen demand from whey wastewater (Mansor et al., 2021), while the combination of ultrafiltration and a membrane bioreactor achieves up to 99% removal (Kumari et al., 2021). Alawamleh et al. (2022) report that combining adsorption and microfiltration ensures up to 98% removal of biological and chemical oxygen demand. Through microfiltration and chromatographic separation, individual components such as glycomacropeptides and immunoglobulins can be isolated (Pires et al., 2024; Zheng & Meletharayil, 2025).

Pressure-driven membrane technologies such as ultrafiltration, reverse osmosis, nanofiltration, and electrodialysis are used for whey processing, improving quality while preserving the biological value of its components (Mirzakulova et al., 2025). Ultrafiltration

represents one of the key methods for obtaining whey protein isolates and concentrates that are used in functional foods (Mc Entee et al., 2025). Among these approaches, membrane technologies are particularly attractive for food applications because they allow component fractionation under relatively mild conditions, thereby preserving protein functionality and reducing thermal damage. Another method for raw material treatment is filtration, after which the obtained whey can be used in infant foods (Muuronen et al., 2021; Rosseto et al., 2024). High-temperature treatment, however, has been observed to negatively affect the quality of the proteins present. For this reason, the choice of treatment should depend on the intended end use of whey, whether for direct beverage production, protein concentration, lactose recovery, or waste minimization.

Whey powder is a dry dairy product produced by concentration followed by drying. Drying is typically carried out by spray drying, which converts liquid whey into powder, facilitating its storage and transportation (Burmistrov et al., 2021; Costa et al., 2025).

The treatment of whey waste before disposal encourages modern approaches to its utilization, particularly for the synthesis of whey protein (Khanam, 2026).

WHEY IN THE FOOD INDUSTRY

Whey has functional and nutritional properties and is therefore incorporated into various food formulations as a biofunctional component – for example, in milk-based products and refreshing beverages. Today, it is increasingly used in the production of environmentally friendly and healthy products, such as fermented drinks and protein snacks.

Whey is a widely used protein ingredient that has been shown to exhibit antimicrobial activity and immunomodulatory properties, to support muscle mass development and body composition optimization, and to contribute to the prevention of cardiovascular diseases and osteoporosis.

Protein-rich whey beverages are commonly associated with post-exercise recovery and may support muscle protein synthesis when consumed as part of an appropriate dietary and training regimen. The use of whey, obtained as a by-product of cheese production, as a beverage for human consumption demonstrates pronounced therapeutic potential with respect to emotional well-being (Korotkova et al., 2020). In the 18th century there were specialized treatment facilities, where it was used as a primary “medical remedy”, with treatments involving the consumption of approximately 4 liters of whey per day. In this context, the inclusion of whey in the daily diet, particularly in its natural (pure) form, may contribute to the optimal functioning of the body. A functional food or beverage is defined as a natural or processed product that, when consumed regularly, does not exhibit toxic effects (Granato et al., 2022) and provides health benefits beyond basic nutrition. In the case of whey, such benefits are associated not only with its protein quality, but also with its versatility as a carrier of probiotics, fruit-derived bioactives, plant extracts, vitamins, and minerals in beverage formulations.

To better illustrate the current diversity of whey utilization in food systems, its main applications can be grouped according to product type, technological role, nutritional relevance, and formulation challenges. Such a structured comparison makes it possible to evaluate whey not only as a dairy by-product, but also as a multifunctional ingredient with broad industrial potential. The principal directions of whey application in modern food production are summarized in Table 1. As shown in Table 1, beverage production remains one of the most promising and versatile directions for whey valorization. This is mainly due to the possibility of combining whey with fruits, probiotic cultures, plant extracts, and other functional ingredients in formulations that are both nutritionally enriched and technologically feasible. For this reason, recent studies have paid particular attention to the development of whey-based beverages with improved sensory properties, enhanced biological value, and greater commercial appeal.

Table 1. Main food applications of whey: products, representative studies, technological advantages, and potential health benefits

Application/ product type	Representative studies	Technological role of whey	Main advantages	Potential nutritional/ functional benefits	Limitations/ challenges
Fruit-based whey beverages	Kolotiy & Kovalenko (2021); Utebaeva et al. (2024)	Liquid base; source of lactose, proteins, and minerals; matrix for flavor incorporation	Improves utilization of liquid whey; enhances sensory appeal through fruit addition; supports product diversification	Hydration; intake of whey proteins and minerals; possible enrichment with fruit antioxidants	Sweet-sour whey flavor must be masked; shelf-life stability; risk of phase separation; consumer acceptance
Fermented and probiotic whey drinks	Kadyan et al. (2021); Özer & Evrendilek (2022)	Fermentation substrate for lactic acid bacteria and yeasts; carrier of probiotic cultures	Adds value to whey; enables production of functional dairy-type beverages; improves microbiological transformation of the substrate	Potential probiotic effect; antimicrobial activity; digestive support; added biofunctional value	Viability of probiotic cultures during storage; acidic taste; process standardization; refrigeration requirements
Protein-enriched sports and recovery beverages	Minj & Anand (2020)	Source of high-quality whey proteins with good digestibility and technological versatility	Easy incorporation into ready-to-drink products; suitable for protein fortification; high market relevance	May support post-exercise recovery and muscle protein synthesis as part of an appropriate diet	Sedimentation and instability in high-protein systems; flavor optimization; higher formulation cost
Whey beverages enriched with plant extracts, vitamins, or bioactive ingredients	Zhuravlev et al. (2021); Rosseto et al. (2024)	Carrier matrix for herbs, plant extracts, vitamins, and complementary proteins	Expands product functionality; increases biological value; allows development of innovative formulations	Antioxidant enrichment; diversified micronutrient profile; broader functional positioning	Possible interactions between whey proteins and plant compounds; taste balance; color and stability issues
Bakery and confectionery products	Minj & Anand (2020)	Emulsifying, foaming, gelling, and water-binding ingredient; partial replacer of other dairy solids	Improves texture, structure, and moisture retention; increases nutritional value; broad applicability in formulations	Higher protein content; improved technological quality of the final product	Thermal sensitivity of proteins; recipe reformulation needed; process adaptation at industrial scale
Dairy formulations, spreads, and sauces	Rocha-Mendoza et al. (2021); Özer & Evrendilek (2022)	Functional dairy ingredient contributing to emulsification, consistency, and solids content	Better resource efficiency within dairy processing; supports reformulation of soft dairy systems and emulsified products	Added proteins and minerals; improved product functionality	Flavor compatibility; labeling and regulatory compliance; need for standardized composition
Whey protein concentrates and whey powder used for food fortification	Blais et al. (2022); Muuronen et al. (2021); Burmistrov et al. (2021)	Concentrated protein ingredient for beverages, snacks, bakery, and specialized foods	Longer shelf life; easier transport and storage; wide industrial applicability	High protein density; convenient fortification of multiple food systems	Processing cost; denaturation risk during heat treatment and drying; reconstitution and solubility challenges

Today, processed whey is used for the production of various types of beverages that have been successfully developed on a small scale. These drinks may be fermented or non-fermented, with or without the addition of flavors, fruit juices or pulp, vegetable extracts, or carbonated components. A large portion of these products have a limited market due to the need for additional equipment for their production (Schulte et al., 2026). This limited market penetration is often related to sensory constraints, insufficient consumer familiarity, short shelf life, and the need for cost-effective stabilization technologies. Over the past decade, whey beverages with added fruit concentrates have been patented. Tropical fruit flavors and citrus tastes are recommended, as they effectively mask the sweet-sour flavor of whey. Positive results have been obtained in studies involving concentrates of mulberry, peach, cherry, and pear. Other flavoring agents used include vanilla, honey, chocolate, and even certain cereals such as bran and oats. Whey can also be used in the production of alcoholic beverages, where lactose-accounting for approximately 70% of the dry matter – plays a major role. Although not widely recognized in some countries, whey is applicable in the production of cream, yogurt, fermented milk, ice cream, or coffee-based beverages. To enhance nutritional and biological value, beverages may be enriched with herbal extracts from medicinal plants with high antioxidant properties, as well as vitamins and proteins (Lima et al., 2022; Rosseto et al., 2024). With modern technologies and developments, whey has become an integral part of the human diet.

The creation of functional beverages from whey mixed with fruit juices is one of the latest trends in its utilization. These beverages improve sensory qualities and extend shelf life (Anichkina et al., 2021; Kolotiy & Kovalenko, 2021; Kaya et al., 2024; Utebaeva et al., 2024). Furthermore, the natural sugars present in fruits can serve as a safe and natural alternative to artificial sweeteners in beverages. It has been demonstrated that high-protein whey may contribute to reducing glycemic response (Minj & Anand, 2020).

The preparation of functional beverages and foods is one of the most promising and important opportunities for managing whey (Kumar., 2023). Functional beverages provide specific health benefits and contribute to the hydration of the body (Navarrete-González et al., 2026). These products may be particularly attractive to younger consumer groups seeking alternatives to conventional soft drinks and protein beverages. Over the past decade, whey and its components have found wide application in the commercial market, particularly in the production of whey-based beverages containing probiotic or prebiotic ingredients (Özer & Evrendilek, 2022). In this context, Kadyan et al. (2021) developed a naturally carbonated probiotic whey-based beverage that demonstrated good antimicrobial activity against pathogenic strains.

An increasing variety of beverages containing whey protein is available on the market. The developed technological processes can be easily integrated into existing production lines, contributing to the minimization of wastewater volumes and reducing treatment-related costs (Kadyan et al., 2021). This creates opportunities for new product development and expansion of the market potential of whey beverages. The literature describes a significant diversity of whey-based beverages.

Beyond beverages, whey proteins are widely applied in bakery, confectionery, dairy, and sauce formulations because of their emulsifying, foaming, gelling, and water-binding properties. In desserts, cakes, and pastries they can improve texture and nutritional value, while in products such as mayonnaise, processed cheese spreads, and meat sauces they may contribute to emulsion stability and consistency. These multifunctional properties make whey ingredients suitable for the reformulation of foods with improved protein content and enhanced technological performance. The Sustainable Development Goals imply the need for dairy producers and processors to take targeted actions to limit the generation of by-products and waste streams, aiming to achieve a more efficient resource cycle through the development of nutrient-rich products by 2030 (Granato et al., 2022). Current challenges in whey-based product development include flavor masking, microbial stability, shelf-life extension, process standardization, consumer acceptance, and cost-effective scale-up. Addressing these issues is essential for the

broader industrial adoption of whey-derived foods and beverages.

CIRCULAR ECONOMY

Whey plays an important role in promoting the circular economy, as this by-product of dairy production can be utilized and transformed into a valuable resource in other sectors of the food industry (Tsermoula et al., 2021). Deproteinized whey can be effectively used for compost production in combination with grape pomace and pruning residues intended for organic farming. In this way, the environmental sustainability of production chains in both the dairy and wine industries is enhanced, while costs associated with by-product management are reduced (Alfonzo et al., 2022).

The by-product of cheese production can also be effectively used for electricity generation. This is mainly achieved through anaerobic digestion, in which the organic matter in whey is converted by microorganisms into biogas rich in methane. The resulting biogas can then be used in combined heat and power systems to generate electricity and thermal energy for dairy plants. It has significant potential to serve as a substitute for fossil fuels. In this way, whey valorization contributes not only to waste reduction but also to partial energy self-sufficiency in dairy processing facilities. Life-cycle assessments indicate that bioethanol production from whey may substantially reduce the environmental burden compared with conventional waste management and fossil-based alternatives (Gosalvitr et al., 2021). Other alternative approaches include the conversion of whey into chemical products.

As noted above, contemporary research focuses on processing methods for the production of biofuels, electricity, and chemical products. These processes are key to the efficient and economically viable utilization of whey. The combination of two or more of these processes enables the production of various high-value products without generating waste in the dairy industry (Asunis et al., 2020).

The valorization of whey is enhanced following initial spray drying, when both acid and sweet whey can be converted into value-added products for the food, cosmetic, and pharmaceutical industries (Soumati et al., 2023). Thanks to modern technologies, high-quality proteins, lactose, minerals, and bioactive compounds can be extracted in accordance with the criteria for sustainable and healthy products (Zhuravlev et al., 2021; Kashung & Karuthapandian, 2025). Russo et al. (2021; 2023) used whey as a substrate for processing algal biomass.

The complete utilization of whey is essential for achieving a full transition of the dairy sector toward a circular economy and for developing strategies designed to address unforeseen situations, such as the coronavirus pandemic of 2019 (Uvarova et al., 2020).

CONCLUSIONS

Whey should no longer be regarded merely as a dairy waste stream, but as a multifunctional raw material with significant nutritional, technological, environmental, and economic value. Its composition makes it suitable for the development of functional beverages, protein-enriched foods, fermented products, and other value-added formulations, while modern purification and biorefinery approaches expand the possibilities for its complete utilization. At the same time, successful whey valorization requires solutions to sensory, technological, logistical, and regulatory challenges. Future research should focus on scalable product development, consumer acceptance, and integrated processing systems that support both circular economy goals and the sustainability of the dairy industry.

REFERENCES

Alawamleh, H., Mousavi, S., Ashoori, D., Salman, H., Zahmatkesh, S., & Sillanpää, M., (2022). Wastewater management using coagulation and surface adsorption through different polyferrics in the presence of TiO2-g-PMAA particles. *Water*, 15, 145.

Alfonzo, A., Laudicina, V., Muscarella, S., Badalucco, L., Moschetti, G., Spano, G., & Francesca, N., (2022). Cellulolytic bacteria joined with deproteinized whey decrease carbon to nitrogen ratio and improve stability of compost from wine production chain by-products. *Journal of Environmental Management*, 304, 114-194.

Anichkina, O., Terekhova, A., Avtsinova, A., Akulina, E., & Dotsenko, E., (2021). Evaluation of the Effectiveness of an Investment Project for the Processing of Whey. *IOP Conf. Ser. Earth Environ. Sci.*, 677, 022055.

Asunis, F., De Gioannis, G., Dessì, P., Isipato, M., Lens, P., Muntoni, A., & Spiga, D., (2020). The dairy biorefinery: Integrating treatment processes for cheese whey valorisation. *Journal of environmental Management*, 276, 111240.

Barba, F., (2021). An integrated approach for the valorization of cheese whey. *Foods*, 10(3), 564.

Blais, H., Schroen, K., Tobin, J., (2022). A Review of Multistage Membrane Filtration Approaches for Enhanced Efficiency during Concentration and Fractionation of Milk and Whey. *Int. J. Dairy Technol.*, 75, 749-760.

Burmistrov, D., Pavkin, D., Khakimov, A., Ignatenko, D., Nikitin, E., Lednev, V., Lobachevsky, Y., Gudkov, S., & Zvyagin, A., (2021). Application of Optical Quality Control Technologies in the Dairy Industry: An Overview. *Photonics*, 8, 551.

Costa, F., Maricato, E., Dias, A., & Baptista, E. (2021). Proteínas Do Soro Do Leite: Propriedades Funcionais e Benefícios Para a Saúde Humana. *Lect. Educ. Física Deport*., 25, 106-120.

Costa, N., Lima, G., Magalhães, C., Arruda, E., Marcuzzo, J., Almeida, G., & Luccas, P. (2025). The Use of Carbon Fiber Restricted Access Material for Cadmium Determination in Milk Whey. *Food Anal. Methods*, 18, 542-551.

Gosalvitr, P., Cuellar-Franca, R., Smith, R., & Azapagic, A. (2021). Integrating process modelling and sustainability assessment to improve the environmental and economic sustainability in the cheese industry. *Sustainable Production and Consumption*, 28 969-986.

Graikini, D., Alvarez-Sabatel, S., Puertolas, E., Perez, M., & Sanchez, L. (2024). Effect of Ultra-High Pressure Homogenization on the Antirotaviral Activity of Bovine Milk Whey. *Innov. Food Sci. Emerg. Technol*., 96, 103745.

Granato, D., Carocho, M., Barros, L., Zabetakis, I., Mocan, A., Tsoupras, A., Cruz, A., & Pimentel, T. (2022). Implementation of sustainable development goals in the dairy sector: Perspectives on the use of agro-industrial side-streams to design functional foods. *Trends in Food Science & Technology*, 124 128-139.

Kadyan, S., Rashmi, H., Pradhan, D., Kumari, A., Chaudhari, A., & Deshwal, G. (2021). Effect of lactic acid bacteria and yeast fermentation on antimicrobial, antioxidative and metabolomic profile of naturally carbonated probiotic whey drink. *LWT*, 142, 111059.

Kashung, P., Karuthapandian, D., (2025). Milk-Derived Bioactive Peptides. *Food Prod. Process. Nutr*., 7, 6.

Kaya, B., Wijayarathna, E., Yuceer, Y., Agnihotri, S., Taherzadeh, M., & Sar, T. (2024). The Use of Cheese Whey Powder in the Cultivation of Protein-Rich Filamentous Fungal Biomass for Sustainable Food Production. *Front. Sustain. Food Syst*., 8, 1386519.

Kim, N., Jeon, J., Elbert, J., Kim, C., & Su, X. (2022). Redox-Mediated Electrochemical Desalination for Waste Valorization in Dairy Production. *Chem. Eng. J*., 428, 131082.

Korotkova, A., Bozhkova, S., Pilipenko, D., & Obrushnikova, L., (2020). Development of low-calorie jelly for complex processing of dairy raw materials. *IOP Conf. Ser.: Earth Environ. Sci.*, 548 082078.

Kolotiy, T. B., & Kovalenko, Z. S. (2021). Drinks based on milk whey using fruit syrup from wild plants. *New Technol*, 17, 33-39.

Kumar, N., Heena, Dixit, A., Mehra, M., Daniloski, D., & Trajkovska Petkoska, A. (2023). Utilization of whey: sustainable trends and future developments. In Whey valorization: Innovations, technological advancements and sustainable exploitation pp. 47-62.

Kumari, R., Ankit, H., & Basu, S., (2021). Reclamation of water from dairy wastewater using membrane bioreactor (MBR) – membrane filtration processes, Mater. *Today: Proc.*, 47(7) 1452-1456.

Khanam, R. (2026). Utilization of Dairy Industrial Waste for Whey and Whey Protein Production. Food Waste Valorization and the Circular Economy.

Larionov, G., Semenov, V., Lavrentyev, A., Sherne, V., Kayukova, O., Mardaryeva, N., & Ivanova, R. (2020). Production of mint whey drink at private and collective farms and agricultural holdings. *IOP Conference Series: Earth and Environmental Science*, 604(1), 012042.

Lima, J., Ribeiro, D., Neto, H., Campos, S., Leite, M., Fortini, M., De Carvalho, B., Almeida, M., & Fonseca, L., (2022). A Machine Learning Proposal Method to Detect Milk Tainted with Cheese Whey. *J. Dairy Sci*., 105, 9496-9508.

Mansor, E., Ali, E., & Shaban, A. (2021). Tight ultrafiltration polyethersulfone membrane for cheese whey wastewater treatment. *Chem. Eng. J*., 407 127175.

Mc Entee, S. A., Kelly, A. L., Lawless, F. N., McCarthy, N. A., & Murphy, E. G. (2025). Effect of ultrafiltration of acid whey at pH 4.6 or 6.5 on whey concentrate composition and resultant powder properties. *International Journal of Dairy Technology*, 78(1), e13116.

Minj, S., & Anand, S., (2020). Whey proteins and its derivatives: Bioactivity, functionality, and current applications. *Dairy*, 1(3), 233-258.

Mirzakulova, A., Sarsembaeva, T., Suleimenova, Z., Kowalski, Ł., Gajdzik, B., Wolniak, R., & Bembenek, M. (2025). Whey: Composition, Processing, Application, and Prospects in Functional and Nutritional Beverages-A Review. *Foods*, 14, 3245.

Muuronen, K., Partanen, R., Heidebrecht, H., & Kulozik, U. (2021). Effects of conventional processing methods on whey proteins in production of native whey powder. *International Dairy Journal*, 116, 104959.

Navarrete-González, R., López-Malo, A., Palou, E., & Ramírez-Corona, N. (2026). A comparative study of theoretical model-based optimization and experimental design approaches for functional beverage formulation. *Sustainable Food Technology*, 4, 947-960.

Özer, B., & Evrendilek, G. (2022). Whey beverages. *In Dairy Foods.* London, UK: Woodhead Publishing House, Elsevier, 117-137.

Paşca, A. L., Odagiu, A., & Coroian, A. (2024). The Power of Whey: Health Benefits of Nature's Protein. *ProEnvironment Promediu*, 17(59), 184-188.

Pires, A., Díaz, O., Cobos, A., & Pereira, C. (2024). A Review of Recent Developments in Edible Films and Coatings-Focus on Whey-Based Materials. *Foods*, 13, 2638.

Rocha-Mendoza, D., Kosmerl, E., Krentz, A., Zhang, L., Badiger, S., Miyagusuku-Cruzado, G., Mayta-Apaza, A., Giusti, M., Jiménez-Flores, R., & García-Cano, I., (2021). Invited review: acid whey trends and health benefits. *J. Dairy Sci*., 104(2), 1262-1275.

Rosseto, M., Rigueto, C., Gomes, K., Krein, D., Loss, R., Dettmer, A., & Richards, N. (2024). Whey Filtration: A Review of Products, Application, and Pretreatment with Transglutaminase Enzyme. *J. Sci. Food Agric*., 104(6), 3185-3196.

Roufou, S., Griffin, S., Katsini, L., Polanska, M., Van Impe, J., & Valdramidis, V. (2021). The (potential) impact of seasonality and cli mate change on the physicochemical and microbial properties of dairy waste and its management. *Trends in Food Science & Technology*, 116, 1-10.

Russo, G., Langellotti, A., Oliviero, M., Baselice, M., Sacchi, R., & Masi, P. (2021). Valorization of second cheese whey through cultivation of extremophile microalga *Galdieria sulphuraria*. *AIMS Environ. Sci*., 8, 435-448.

Russo, G., Langellotti, A., Verardo, V., Martín-García, B., Oliviero, M., Baselice, M., Di Pierro, P., Sorrentino, A., Viscardi, S., Marileo, L., Sacchi, R., & Masi, P. (2023). Bioconversion of Cheese Whey and Food By-Products by Phaeodactylum Tricornutum into Fucoxanthin and n-3 Lc-PUFA through a Biorefinery Approach. *Mar. Drugs*, 21, 190.

Sinđić, M., & Pajic, M. (2025). Implementation of Good Hygiene Practices in a Milk Processing Plant. *In Proceedings of the 3rd International Symposium on Biotechnology, Čačak, Republic of Serbia*, 369-376.

Soumati, B., Atmani, M., Benabderrahmane, A., & Benjelloun, M. (2023). Whey Valorization - Innovative Strategies for Sustainable Development and Value-Added Product Creation. *J. Ecol. Eng*., 24, 86-104.

Schulte, H., Hartfiel, C., Maas, J., Scherbanjow, J., Mühlbrodt, S., Schleyerbach, U., & Bornkessel, S. (2026). Food upcycling beyond the big players: the potential of food upcycling in artisanal food production based on new product developments. *British Food Journal*, 128(1), 136-151.

Švikruhová, P., Kapsdorferová, Z., & Kataníková, R. (2022). Current situation of milk producers and their needs for upcoming programming period. *International Journal of Sales, Retailing and Marketing*, 86.

Tsermoula, P., Khakimov, B., Nielsen, J., & Engelsen, S. (2021). Whey-The Waste-Stream That Became More Valuable than the Food Product. *Trends Food Sci. Technol*., 118, 230-241.

Uvarova, I., Atstaja, D., Grinbergs, U., Petersons, J., Gegere-Zetterstroma, A., & Kraze, S. (2020). Transition to the Circular Economy and New Circular Business Models-An in - Depth Study of the Whey Recycling. *IOP Conf. Ser. Earth Environ. Sci*., 578, 012019.

Utebaeva, A. A., Alibekov, R. S., Sysoeva, M. A., Orymbetova, G. E., Ablash, A. A., & Abish, Z. H. (2024). Functional whey-based drinks with grape pomace extract and fruit juice. *J. Almaty Technol. Univ.*, 145, 26–38.

Vera-Santander, V., Hernandez-Figueroa, R., Arrioja-Breton, D., Jimenez-Munguia, M., Mani-Lopez, E., & Lopez-Malo, A. (2024). Utilization of Whey for Eco-Friendly Bio-Preservation of Mexican-Style Fresh Cheeses: Antimicrobial Activity of Lactobacillus Casei 21/1 Cell-Free Supernatants (CFS). *Int. J. Environ. Res. Public Health*, 21, 560.

Zandona, E., Blažić, M., & Režek Jambrak, A. (2021). Whey utilization: Sustainable uses and environmental approach. *Food technology and biotechnology*, 59(2), 147-161.

Zheng, H., & Meletharayil, H. (2025). Constructing Aqueous Foams from Milk Components: Structure and Interfaces. *Curr. Opin. Food Sci.*, 63, 101290.

Zhuravlev, S., Serova, O., & Bozhkova, S. (2021). The Use of Plant Extracts in the Production of Whey Beverage. *IOP Conf. Ser. Earth Environ. Sci*., 848, 012034.

Zotta, T., Solieri, L., Iacumin, L., Picozzi, C., & Gullo, M. (2020). Valorization of cheese whey using microbial fermentations. *Appl. Microbiol. Biotechnol*., 104(7), 2749-2764.

WILD LIFE MANAGEMENT, FISHERY AND AQUACULTURE