



SUSTAINABLE MANAGEMENT OF WHEY GENERATED FROM CHEESE PRODUCTION IN THE LAKE ÇILDİR BASIN AND ADJACENT COMMUNITIES

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Abstract: This study has been prepared based on information obtained from field visits conducted at various times between 2006 and 2020, primarily within the Lake Çıldır Basin as well as in the provinces of Kars and Ardahan, under the coordination of the 'Lake Çıldır Basin Conservation Plan' project, together with data collected from local institutions and relevant literature. As is well known, whey is a highly valuable by-product formed during cheese production; however, if it is not managed sustainably, it can turn into a waste that causes severe pollution to the environment, or in other words, to the ecosystem in which it exists. Since small-scale enterprises are predominant in the settlements within and around the Lake Çıldır Basin, the processing of whey and its conversion into high value-added products is one of the major issues awaiting a solution. According to preliminary field assessments, it has been concluded that a stationary whey processing system would initially be capable of addressing this problem. In this way, an additional source of income would be provided to support the local economy and livestock production, while also protecting the ecology of the region from pollution originating from whey discharge.

Keywords: Whey, Lake Çıldır basin, Sustainable waste management, Cheese production

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Received: November 08, 2025

Accepted: December 15, 2025

Published: January 15, 2026

Cite as: Güneş, K. (2026). Sustainable management of whey generated from cheese production in the Lake Çıldır basin and adjacent communities. *Black Sea Journal of Agriculture*, 9(1): 100-104.

1. Introduction

Cheese production dates back to prehistoric times, with various sources indicating periods between 7000 and 10000 BC (Durlu-Özkaya and Gün, 2007; Güzeler and Yıldırım, 2016). Findings from the Göbeklitepe excavations, regarded as the "zero point of history," suggest that the origins of cheese-making culture in this cradle of civilization may extend even further back in time. Cheese production is a cultural practice that varies widely among societies. Each cheese type has evolved from prehistoric times, shaped by the customs and traditions of the societies in which it was produced, resulting in significant differences in taste, texture, aroma, shape, and salinity.

In Türkiye, in addition to the most common type white cheese it is known that approximately 150 varieties of cheese exist. However, with detailed local research, this number could be several times higher, potentially reaching into the thousands. Among the regionally known cheeses are Ezine, Kars gruyère, Kars kaşar, Trakya Kaşar, Mihaliç, Urfa White Cheese, Antep, İzmir tulum, and Erzincan tulum, among many others. It is reported that about 50 traditional cheese types exist in the Eastern Anatolia Region alone (Güzeler and Koboyeva, 2020). Among these, Kars gruyère has the

highest dry matter content at approximately 68.20% (Ulutaş et al., 1993). When Kars and its vicinity are considered, about 6–7 of these cheese varieties are believed to have industrial production potential (Baburşah and İnce, 2025). According to 2021 data, 26 types of cheese produced in Türkiye have received geographical indication registration (TTOD, 2021). These include: Antakya carra cheese, Antakya moldy sürkü, Antakya sürkü, Antep/Gaziantep sıkma cheese, Bolu keş, Diyarbakır örgü cheese, Edirne white cheese, Erzincan tulum cheese, Erzurum civil cheese, Erzurum moldy civil cheese, Ezine cheese, grana padano, Gümüşhane deleme cheese, halloumi, Karaman divle cave tulum cheese, Kars kaşar, Kırklareli white cheese, Malkara aged kaşar, Manyas kelle cheese, Maraş parmak/sıkma cheese, parmigiano reggiano, Pınarbaşı Uzunyayla Circassian cheese, Sakarya Abkhaz cheese, Vakfıkebir külek cheese, Van herb cheese, and Yozgat çanak cheese. Additionally, 24 other traditional cheeses have pending applications for geographical indication (TTOD, 2021).

According to 2024 data from the Turkish Statistical Institute (TÜİK), the total cheese production in Türkiye was 847,579 tons, while 1,236,456 tons of whey (in solid and concentrated form) were generated as by-products. In addition, 63,536 tons of whey powder or blocks were



animal husbandry. For this reason, the evaluations concern all settlements in the provinces of Kars and Ardahan.

3. Results and Discussion

The main focus of this study is to demonstrate how whey, a valuable by-product of cheese production, can be transformed into high value-added products while ensuring sustainable management of the remaining waste. To provide a general idea about the region, the Chemical Oxygen Demand (COD) values of whey samples taken from three different family enterprises in the districts of Sarıkamış and Çıldır in the years 2006, 2007, and 2017 were analyzed, and their COD values were recorded respectively as 72,000 ppm, 94,000 ppm, and 126,000 ppm. Instead of deriving an average result from this limited number of data, the evaluation of the average COD value of whey was based on examining other studies conducted worldwide. When numerous comprehensive studies carried out globally are reviewed, it is observed that this value is at least 60,000 ppm and sometimes recorded above 100,000 ppm (Chatzipaschali and Stamatis, 2012; Cruz-Salomón et al., 2020; Estikomah et al., 2023; Besediuk et al., 2024; Selmi et al., 2025). The reason for this variable concentration can be explained by the lactose and fat content in milk, which is directly related to the species, breed, nutrition level, age, and other conditions of the animals from which the milk is obtained. Since this study is a preliminary one and data are limited, it was concluded that under the conditions of the study area, the COD value of whey can be considered approximately 100,000 ppm. Indeed, similar results were obtained from samples collected from other geographical regions in Türkiye (Marmara and Thrace Regions). Even if the lower concentration of whey with high pollution potential is taken as 60,000 ppm, its direct discharge into the receiving environment is extremely harmful to the ecosystem where it is released. In other words, if the concentration range given above is taken as the basis, 1 liter of whey contains pollutant levels approximately equivalent to 120–200 liters of domestic wastewater. This is because the COD concentration of a medium-strength wastewater is considered to be approximately 500 ppm (Tchobanoglous and Burton, 1991). Therefore, discharging untreated whey even after simple treatment poses serious environmental challenges, particularly due to its high salt content.

The most rational approach is to establish a whey processing facility that extracts valuable components such as proteins, lactose, vitamins, and minerals and then treats the remaining wastewater using appropriate technologies. These valuable components can be recovered through membrane or evaporator technologies. However, the high initial investment cost has prevented many Turkish dairy producers from adopting these systems. According to a study by SERKA (2020), a whey processing facility with a capacity of 200 tons/day cost approximately 34 Million Turkish Liras

(MTL) in 2020, equivalent to about 165 MTL at November 2025 prices (SERKA, 2020). If such systems are imported as turnkey packages, the cost would at least double.

Consequently, the high cost and the short production season (mostly between April and August due to climatic conditions) are the two main reasons why such investments have not yet been made in the region. However, the declining cost of membranes and the growing expertise of local firms indicate that it is now possible to build region-specific, lower-cost systems. For these systems to operate efficiently, a continuous supply of whey must be ensured. Therefore, the first step is to establish a practical collection and supply network. The second step involves identifying the most suitable combination of membrane evaporator biological treatment modules that can be manufactured locally at low cost and determining the characteristics of the recovered products based on regional and national needs. Ultimately, the goal is to generate income from a substance traditionally regarded as waste while preventing environmental pollution and creating awareness and employment opportunities.

Preliminary studies should also evaluate whether the value-added products obtained from whey will be marketed locally or nationally. Based on this, it is essential to determine whether the final product will be pure protein (whey protein), pure lactose, a protein lactose mixture (whey powder), or whether it will be sold in liquid or solid form. For the development of agro-based industries in the region, producing simpler and lower-cost products such as cream or slurry using appropriate technologies products that can be incorporated into bread, pasta, yogurt, ice cream, and biscuits would be the most practical solution.

The cheapest way to utilize these high-protein, high-mineral products in various food applications is to produce them locally, as transportation costs constitute the major component of overall expenses. Locally produced products can then be distributed through wider marketing networks.

To feasibly produce the targeted products and ensure that the remaining wastewater is safely treated, it is crucial to determine which combination of modules ultrafiltration, nanofiltration, reverse osmosis, evaporation, spray drying, and biological treatment should be integrated. This approach will help minimize capital investment costs while ensuring that the treated effluent complies with environmental regulations. In the treatment process, it is mandatory to take as a basis and evaluate, according to the system to be constructed, the provisions and standards in the 'Waste List' and 'Waste Code' included in the annex of the 'Waste Management Regulation' published in the Official Gazette dated 2 April 2015 and numbered 29314; Table 5.3 included in the annex of the 'Regulation Amending the Water Pollution Control Regulation' published in the Official Gazette dated 17 December 2022 and numbered 32046; and

Tables 1 and 2 of the 'Regulation Amending the Urban Wastewater Treatment Regulation' published in the Official Gazette dated 08.01.2006 and numbered 26047. In addition to the aforementioned low-cost products, the production of more expensive yet considerably higher value-added products may also serve as a secondary objective. Such products typically possess longer shelf lives and can yield outcomes that address both domestic market demands and export opportunities. Although in many countries' proteins, lactose, vitamins, and minerals are individually produced from whey, producing whey powder a composite of these valuable components offers a significantly more cost-effective alternative. Otherwise, separate production of these components would require the installation of costly ultrafiltration and either nanofiltration or reverse osmosis systems to separate proteins from lactose. To obtain whey powder, the desired outcome can be achieved by integrating a drying unit following a nanofiltration unit within the processing system. When an efficient nanofiltration system is established, the residual wastewater after the extraction of most valuable components can be effectively treated in a biological wastewater treatment unit. Within this context, the wastewater generated from the whey processing facility, whose pollutant load is reduced to a level suitable for treatment in a biological wastewater treatment plant (by at least 90–95%), should either be conveyed to the nearest biological treatment system or treated in a facility constructed for this purpose within the whey processing plant area. In other words, by selecting appropriate membrane systems, it is possible to reduce the COD value of raw whey, which is approximately 100,000 ppm, to 5,000 ppm, or even to 2,000 ppm with advanced membrane technologies. Consequently, the pollutant load directed to a newly constructed or existing biological wastewater treatment facility would be significantly reduced, thereby facilitating much easier treatment. The most critical point to be emphasized here is that the whey processing facility and the biological wastewater treatment plant intended for the treatment of the remaining effluent must be constructed simultaneously. Failure to do so may result in severe ecological damage.

4. Conclusion

Whey is a valuable resource that should be utilized to produce high value-added products, thereby enabling cheese producers to increase their income not only from cheese itself but also from the by-products of production. Establishing whey processing facilities in Kars and Ardahan is feasible largely through domestic means, making local solutions far more practical than costly imported systems. By developing joint projects, local universities can help integrate unutilized whey into the regional economy. Moreover, treating the residual wastewater after valuable components are recovered will provide an invaluable environmental benefit, preventing pollution while creating economic and social gains.

Research gaps: In the absence of whey processing facilities, it would be highly beneficial to monitor soil salinity and groundwater salinity levels in the vicinity of settlements engaged in cheese production and to compare these measurements with reference sites in the region. Such an approach would allow the development and implementation of a data-driven action plan, ensuring more coherent and effective mitigation measures. Moreover, addressing this gap offers an opportunity for universities in the region to develop original research projects and generate valuable scientific findings.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	K.G.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

Acknowledgements

The author expresses his gratitude to the TÜBİTAK Marmara Research Center and the Serhat Development Agency (SERKA) for their support during the project and field studies.

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