



## Valorization of Traditional Dairy Byproducts: A Case Study of Kyrgyz Chobogo within Circular Food Systems

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### ABSTRACT

The transition toward sustainable and circular food systems has increased interest in valorizing underutilized dairy by-products. This study focuses on Kyrgyz Chobogo, a by-product of clarified butter (Sary-Mai) production, with the aim of transforming it into a value-added ingredient within the dairy production cycle. Despite its cultural importance and growing consumption, Chobogo remains underexplored in scientific literature. Therefore, a comprehensive analysis was conducted to evaluate its physicochemical properties, nutritional composition, fatty acid and amino acid profiles, sensory attributes, and microstructure. Results indicate that Chobogo is a highly concentrated dairy product, with high total solids (90.99 g/100 g) and energy density (620 kcal/100 g). Lipids are the predominant component (53.10 g/100 g). Notably, a wide range of essential and conditionally essential amino acids was preserved despite thermal processing, suggesting maintained protein quality. The fatty acid profile showed a balance between saturated (68.85%) and monounsaturated fatty acids (25.50%). Sensory evaluation revealed high overall acceptability, supported by microstructural analysis, which showed a porous and heterogeneous matrix formed through heat-induced transformations. These findings demonstrate that Chobogo should not be considered merely a by-product, but rather a nutritionally valuable and economically beneficial dairy ingredient. Its valorization aligns with circular economy principles by promoting efficient use of milk resources and reducing waste. This study provides a scientific foundation for future standardization, safety assessment, and integration of Chobogo into modern food systems as a sustainable and culturally significant dairy component.

**Keywords:** Kyrgyz chobogo, Dairy byproduct valorization, Circular food systems, Traditional dairy products, Sustainable processing

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### INTRODUCTION

The global food system is under pressure to meet a number of objectives, including environmental sustainability and nutritional demands. Among the top priorities are reducing food waste and improving raw material utilization, particularly in resource-intensive businesses like the dairy sector. In this way, circular food systems are a strategic paradigm that aims to maximize the value of primary agricultural products while minimizing consumer streams of waste (Obayomi *et al.*, 2026). Dairy processing generates a wide range of secondary fractions,

some of which are currently underutilized despite their nutritional importance. While some byproducts, like whey and buttermilk, have been effectively exploited in food, medicinal, and functional applications, others remain underused, particularly those produced on a traditional and small-scale basis. Such ignored fractions represent a dormant potential for both sustainable innovation and cultural preservation (Tarchi *et al.*, 2024).

Dairy production in Central Asia is also entrenched in nomadic practices, where efficiency and complete resource exploitation have been the main driver to survival. A good example of such systems is Kyrgyzstan, where a range of products are converted out of milk based on the mobility of the season and a lack of storage facilities. The clarified butter- butter domestically

referred to as Sary-Mai, is one of the most popular products that boasts a long shelf life and richness in energy (Sakhanova, 2009). Nonetheless, in its production, another by-product is formed, namely, Chobogo, that has been adorned with very little scientific interest, despite the routine use of the product in the local societies. Chobogo is developed in the thermal clarification of cream, where the solids of milk pass through the complex physicochemical changes, which involve the coagulation of the proteins and caramelisation of the lactose. The resultant product is a thick, brown dairy processing that used to be in the form of an energy-dense snack, especially amongst herders and children. Although widely culturally appropriate and used in more households, Chobogo is largely unrecorded in the scientific literature and not under regular production and safety guidelines (Smanalieva *et al.*, 2022).

In the context of the circular economy, chobogo is a good example of a byproduct that can be found in nature and follows the principles of zero waste. Its heroism might help minimize the losses among dairy processing chains and make new value-added products. However, in order to achieve successful valorization, it is necessary to understand how it is composed and what structural properties and possible functional benefits it may have, particularly in terms of bioactive compounds and antioxidant potential (Ahmed, 2023). In the absence of this knowledge, it has limited shifting its informal use to wide applications. In addition, the processes of the production of chobogo are associated with transformation that may imply that chobogo can have its own nutritional and functional features. The concentration of proteins (and lipids) by heat can positively impact energy density, alter the protein shapes, and alter lipid composition, which may have an impact on digestibility, bioavailability, and sensory properties (Akuzawa *et al.*, 2011). The following considerations are especially pertinent when focusing on the current dietary trends, where interest in food products rich in nutrients, traditionally oriented, and low-waste food products grows. Even despite these encouraging qualities, comprehensive scientific information to explain the physicochemical, nutritional, and structural properties of Chobogo is missing. This is a weakness that restricts its awareness in academic research and industrial innovation. This is a critical problem that has to be addressed in order to validate traditional knowledge and also ensure that such products are incorporated as sustainable food systems (Ait-Kaddour *et al.*, 2024).

Thus, this paper seeks to assess Kyrgyz Chobogo by considering the framework of the circular food and byproduct valuation. Offering an in-depth discussion of its content and characteristics, this piece attempts to provide a scientific basis of its possible application as a functional dairy product, as well as playing a role in a larger initiative to sustainably use available resources and modernize the use of traditional food processes.

## MATERIALS AND METHODS

### *Raw materials*

The raw cow milk (100 L) required to make Chobogo was bought from the Alaiku Organics dairy facility in Osh, Kyrgyzstan. Fat 3.6, protein 3.1, lactose 4.5, solids-not-fat 8.5, total solids 12.1, pH 6.7, and density 1.028 g/cm<sup>3</sup> were the characteristics of the milk produced by stall-fed cows. The milk was processed within 24 hours of collection at a storage

temperature of 5°C and had a normal sensory quality, clean-milky taste, and no off odors.

### *Production of chobogo*

Chobogo was processed using a conventional processing plan where the cream was clarified using thermal treatment. Raw milk was filtered with the help of a 50 µm nylon filter to eliminate mechanical contaminants and pasteurized at 65 - 7°C for 30 min. The centrifugal separator was used to separate the cream after it was cooled to 45°C (GEA MSE-500-01-777, Italy). The cream (fat content of cream was about 68%) was cooled down to 5-7°C and left to cool down for 12 h to encourage crystallization of the fat. This was followed by the addition of 3 kg of ripened cream, which was heated slowly (between 110 and 120°C) with on-going stirring. Protein coagulation and lactose caramelization as well as the evaporation of moisture took place during heating. After a light brown residue was obtained, the mixture was filtered in order to obtain clarified butter (Sary-Mai) and the solid fraction (Chobogo). The ultimate production was about 1820 g of Sary-Mai and 270 g of Chobogo.

### *Physicochemical analysis*

All analyses were done in triplicate (n = 3). The digital pH meter, which had been adjusted to allow a zero, was used to measure pH. To determine titratable acidity (g lactic acid/100 g), it was done in respect to ISO 11869:2012. ISO 5534:2004 was used to measure moisture and total solids; AOAC (2005) was used to assess ash content; ISO 23319:2022 measured lactose (using the HPLC method); and ISO 8968-3:2004 measured protein content (using the Kjeldahl-based method). The colour parameters (L, a, b, c, h) were measured with the help of Chromameter CR-400 (Konica Minolta, Japan) according to the CIE Lab system called Lab. The contribution of the properties of the texture was tested with a CT3 texture analyzer (Brookfield, USA) under compression conditions of standard conditions.

### *Amino acid and fatty acids analysis*

The composition of the amino acids was assessed in ultrafast liquid chromatography (UFLC) derivatized in the pre-column (OPA/FMOC method). Samples (approximately 0.4 g) were hydrolyzed in 6 M HCl at 103°C over 24 h, which was neutralised and buffered. Calibration and analysis of filtered hydrolysates were done on a Shimadzu UFLC system, which can house up to 1000 ml of a column along with a fluorescence detector and a YMC-Triart C18 column. The quantification was done by using calibration standards within the desired concentration ranges. The procedure helped to recognize necessary, contingently necessary, and non-essential amino acids. Two grams of the samples were transferred to n-hexane, whereby the sample was converted to methyl acids as per the ISO 12966-2:2017. A Shimadzu GC-2010 (flame ionization detector) system, equipped with a Restek Rt-2560 capillary column, was used to conduct the gas chromatographic analysis. Comparison with standard mixtures was used to identify fatty acids, which were then expressed in g/100 g of total fatty acids. The lipid fractions were divided into saturated (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA), omega-3 and omega-6 forms. This has included health-related lipid indices (atherogenicity, thrombogenicity, and hypocholesterolemic/hypercholesterolemic ratio) in

determining the quality of nutrition.

#### *Sensory evaluation and microstructure analysis*

In accordance with ISO 8586:2023 norms, a panel of seven qualified assessors evaluated sensory qualities. A standardized 10-point scale (ISO 4121:2003) was used to evaluate samples under controlled conditions in terms of appearance, scent, texture, taste, and overall acceptability. The panelists received training so that their interpretations of the qualities would be consistent. To ascertain the variability and repeatability of sensory perception, statistical analysis of the data was employed. Microstructural parameters were investigated using scanning electron microscopy (SEM) (Mira3, Tescan, Czech Republic). The samples were cut into 0.4 x 0.4 cm pieces and adhered to the silicon wafers without the use of any adhesive. Prior to analysing the high vacuum, the sample was examined using secondary and backscattered electron detectors at 5 kV acceleration voltage and 1000x magnification to evaluate the internal structural organization and surface morphology (Babaei et al., 2023; Khazri et al., 2024; Liu et al., 2024).

#### *Statistical analysis*

All measurements were performed in triplicate, and results are presented as mean  $\pm$  standard deviation. Statistical analysis was conducted using SPSS (version 24, USA). Since the research was carried out using only one production batch, it was susceptible to the analysis of only descriptive statistics evaluating the measurement repeatability and internal variability. There was no application of inferential statistical testing, but the level of significance of 0.05 is pointed at as the level of significance to be used in future comparative studies (Aksoy & Akaydin, 2024; Jegede, 2024; Kovalchuk et al., 2024; Ahmed & Rajasekar, 2025; Drissi et al., 2025).

## RESULTS AND DISCUSSION

### *Physicochemical properties of chobogo*

#### *Acidity and pH*

The acid-base properties of Chobogo, the titratable acidity measured 0.15 g/100 g with another error of 0.01, and the pH was 5.49 g/100 g, which suggests that the system was mildly acidic. These values are a non-fermented chemically altered dairy matrix in which the acidity is mainly affected by the concentration effects and, secondly, by heat-induced alterations and not fermentation by the microbes. The buffering ingredients are redistributed apparently because of protein denaturation and concentration of soluble acids with the lower pH, indicating that buffering components are redistributed during thermal processing as compared to in raw milk. The low standard deviation of both parameters would show that both the processing conditions are highly reproducible, which is the key to possible industrial standardization. Circular food systems in this context allow this byproduct to be converted into some type of consistent and controlled value-added product due to this type of stability.

#### *Color characteristics*

The color analysis has shown that Chobogo is dark, in saturated brown, with  $L = 36.5 \pm 0.8$ ,  $a = 10.2 \pm 0.3$ , and  $b = 22.4 \pm 0.5$

values, indicating heavy reliance on yellow-red, which is one of the traits of thermally processed dairy solids. The L-value is rather low, which means it has less lightness, and the a- and b-values are higher, which means that reddish and yellow pigments are formed. These modifications are in line with Maillard reaction and lactose caramelization reactions, which take place at long heating conditions and temperatures higher than 100°C, crucial in ensuring reproducibility of the process. Notably, the small variation in colour parameters indicates homogenic heat transfer and reaction kinetics, which is imperative to reproducibility in the process. It is not just a part of a processing but a valuable feature in a valorisation framework associated with the development of flavors.

#### *Microstructural characteristics*

The SEM analysis showed an irregular, porous microstructure that consisted of irregular surfaces, pores, and aggregated clumps. The structure included different sizes and distributions of micropores, dense protein-lipid aggregates, and crystalline-like formations. This heterogeneity of the structure describes the complicated physicochemical changes that are experienced during the clarification of the cream. The combination of protein coagulation, fat phase separation, and precipitation of the minerals will help create a multi-component matrix. The presence of pores and fractures implies loss of moisture and local contraction of solids as models during heating, and the existence of aggregated clusters confirms the local concentration of solids. Functionally, such a structure could affect perception of the texture (firmness, granularity), release of fat during mastication, possible behaviour of rehydration, or incorporation of the ingredients. These aspects contribute to considering Chobogo as structurally functional material, instead of inert residue, and support its applicability in the valorisation strategies.

#### *Sensory profile*

The general acceptability was high at  $8.50 \pm 0.84$ ; thus, there was a high approval of the panels. Sensory qualities include texture ( $7.70 \pm 1.41$ ), consistency ( $7.86 \pm 1.87$ ), oiliness ( $8.10 \pm 0.84$ ), sweetness ( $7.20 \pm 1.09$ ), and sour scent ( $8.20 \pm 1.72$ ). The panelists consistently described the product as having a thick, oily texture and a well-balanced flavour profile that included roasted, acidic, and sweet notes in their mouths. The comparatively low to moderate variability across qualities demonstrates dependable sensory perception and product homogeneity. Notably, the high scores for oiliness and sour aroma suggest that both lipid content and mild acidity contribute significantly to the overall sensory experience. From a circular food systems perspective, these results demonstrate that Chobogo is not simply a processing residue but a sensorially acceptable and culturally validated product, supporting its transition from informal consumption to potential commercial application.

#### *Nutritional composition*

##### *Proximate composition and energy value*

According to the compositional profile (**Table 1**), Chobogo is a very concentrated dairy product because its dry matter percentage is 90.99 g/100 g + 0.10 g. The key elements are Fat:

53.10 ± 0.06 g/100 g, Carbohydrates: 23.60 ± 0.10 g/100 g, Protein: 11.93 ± 0.01 g/100 g, and Ash: 2.36 ± 0.05 g/100 g, as shown in **Table 1**.

The energy content calculated was 620.0 1± 1.0 kcal/100 g, and it proved that the product contains a lot of calories. This composition indicates the concentration of the milk solids by the thermal treatment, where the effect of eliminating water brings about an increase of the macronutrients. The most common fraction is fat, followed by carbohydrates (mainly

residual lactose and its transformation products) and proteins. The interpretation of the data can be supported by the low standard deviations observed in all the parameters that result in the analytical accuracy and compositional stability, which prove that the information is reliable. In terms of valorization, the results indicate that Chobogo still has a large percentage of nutritionally beneficial ingredients, which turn otherwise wasted content into a rather thick and nutritious food source.

**Table 1.** Proximate composition and energy content of Kyrgyz Chobogo expressed on a fresh weight basis (mean ± SD, n = 3).

Sample	Total solids (g/100 g)	Lipids (g/100 g)	Protein (g/100 g)	Mineral content (g/100 g)	Available carbohydrates (g/100 g)	Energy (kcal/100 g)
Chobogo	90.99 ± 0.10	53.10 ± 0.06	11.93 ± 0.01	2.36 ± 0.05	23.60 ± 0.10	620.0 ± 1.0

#### Amino acid profile

The amino acid composition (**Table 2**) show that Chobogo has a wide range of amino acids, which consists of essential, conditional and non-essential classes.

Non-essential amino acids include glutamic acid (2.10 ± 0.14 μmol/L) and aspartic acid (0.95 ± 0.07 μmol/L). Some fundamental amino acids are leucine (0.96 ± 0.03 μmol/L, highest), threonine (0.56 ± 0.04 μmol/L), and valine (0.48 ± 0.02 μmol/L). The conditionally necessary amino acids arginine, glycine, and tyrosine were present in modest concentrations. All of the essential amino acids are present, which means that even after thermal processing, protein integrity is preserved to a great extent. This is especially critical because treatment at high temperatures tends to cause the degradation of amino acids or to decrease their bioavailability. Minimal inter-replicate variation also ensures method reliability and compositional stability. This profile outlines the classification of Chobogo as a nutritionally functional protein source that will provide it with a higher value than that of an unsophisticated byproduct under a circular systems perspective.

**Table 2.** Distribution of essential, conditionally essential, and non-essential amino acids in Kyrgyz Chobogo (μmol/L, mean ± SD, n = 3).

Amino acid group	Amino acid	Content (μmol/L)
<b>Non-essential</b>	Aspartic acid	0.95 ± 0.07
	Glutamic acid	2.10 ± 0.14
	Serine	0.58 ± 0.04
	Alanine	0.35 ± 0.02
<b>Conditionally essential</b>	Glycine	0.40 ± 0.01
	Arginine	0.38 ± 0.02
	Tyrosine	0.44 ± 0.03
	Cysteine	0.28 ± 0.04
	Proline	0.22 ± 0.01
<b>Essential</b>	Histidine	0.23 ± 0.02
	Threonine	0.56 ± 0.04
	Valine	0.48 ± 0.02
	Methionine	0.31 ± 0.05
	Phenylalanine	0.49 ± 0.02
	Isoleucine	0.47 ± 0.01
	Leucine	0.96 ± 0.03
	Lysine	0.39 ± 0.08

#### Fatty acid profile

The fatty acid composition (**Table 3**) shows that saturated fatty

acids (SFAs) are prevalent, 68.85 ± 0.10 percent of total fatty acids. The big SFAs are palmitic acid (C16:0): 29.74 ± 0.02%, stearic acid (C18:0): 11.29 ± 0.01%, and myristic acid (C14:0): 11.07 ± 0.01%. There were also short- and medium-chain fatty acids (e.g., C4:0, C6:0, and C10:0) that serve to add to the metabolic and sensory properties. Unsaturated fatty acids were 31.13 and they included MUFAs: 25.50 ± 0.07% (mainly oleic acid, 22.39 ± 0.04%); PUFAs: 2.92 ± 0.03%; the omega-6/omega-3 ratio was 5.94 ± 0.06; and total trans fatty acids were 2.71 ± 0.01%. The health-related indices were computed as Atherogenicity index (AI): 2.71, thrombogenicity index (TI): 2.86, h/H ratio: 0.35, desirable fatty acids (DFA): 42.41. Domination of SFAs is due to the composition of dairy fat, but the presence of MUFAs and PUFAs represents a healthy lipid profile. The ratio of omega-3 is within reasonable nutritional limits. According to the point of view of valorization, the lipid profile suggests that Chobogo still has a functionally and nutritionally relevant misfat percentage, which can be used in energy-rich products or in some dietary niche.

**Table 3.** Long-chain fatty acids (LCFA), Medium-chain fatty acids (MCFA), Short-chain fatty acids (SCFA), Monounsaturated fatty acids (MUFA), Polyunsaturated fatty acids (PUFA, ω-6), Polyunsaturated fatty acids (PUFA, ω-3), Trans fatty acids (TFA)

Category	Fatty acid	Content (% of total FA)
<b>Long-chain fatty acids (LCFA)</b>	C14:0	11.07 ± 0.01
	C15:0	1.30 ± 0.00
	C16:0	29.74 ± 0.02
	C17:0	0.86 ± 0.00
	C18:0	11.29 ± 0.01
<b>Medium-chain fatty acids (MCFA)</b>	C10:0	2.71 ± 0.01
	C12:0	3.10 ± 0.01
<b>Short-chain fatty acids (SCFA)</b>	C4:0	3.77 ± 0.11
	C6:0	2.24 ± 0.02
	C8:0	1.25 ± 0.01
<b>Monounsaturated fatty acids (MUFA)</b>	C14:1	0.89 ± 0.00
	C16:1	1.81 ± 0.01
	C18:1	22.39 ± 0.04
	Other MUFA	0.14–0.26*
<b>Polyunsaturated fatty acids (PUFA, ω-6)</b>	C18:2	2.23 ± 0.01
	Other ω-6	0.01–0.15*

Polyunsaturated fatty acids (PUFA, $\omega$ -3)	C18:3 $\alpha$	0.31 $\pm$ 0.00
	Other $\omega$ -3	0.03–0.08*
Trans fatty acids (TFA)	C18:1 trans	2.57 $\pm$ 0.01
	C18:2 trans	0.14 $\pm$ 0.00
	Total TFA	2.71 $\pm$ 0.01

This paper gives a new understanding of the valorization capability of Chobogo by analyzing its physicochemical, nutritional, and structural properties in the framework of the circular dairy systems. These results show that Chobogo, considered a by-product of butter clarification, still has significant nutritional and functional properties believed to justify its repositioning as a dairy ingredient resource and not a by-product. Physicochemical characteristics of chobogo are indicative of effects of thermal concentrating processes on dairy matrices. The titratable acidity (0.15 g/100 g) and pH (5.49) observed can be attributed to non-fermented, heat-treated dairy systems where acidification is influenced by the concentration of the milk components and slight reaction of heat but not fermentation. This behavior was also observed in thermally treated milk products, as interruption in buffering mechanisms and salt repartition causes a significant drop in pH (Ahmadi *et al.*, 2024). These properties imply that Chobogo can be stored or further processed in the form of a chemical, which is of special significance when considering its incorporation into value-added applications (Ahmadi *et al.*, 2024).

The formation of color in Chobogo is tightly linked with Maillard reactions and lactose caramelization that are present during heating. The reduced lightness (L) and high levels of red-yellow (a, b) are similar to the results with heat-treated dairy solids (Chudy *et al.*, 2020). These changes, rather than signaling degradation will add flavor complexity and interest to consumers. Such thermally induced qualities might be useful in increasing the desirability of products in the context of valorization, i.e., in the context of converting the byproducts into commercially viable foods. Microstructural studies demonstrated that the matrix was heterogeneous and porous and was created through coagulation of proteins, redistribution of fats, as well as aggregation of minerals. Other structural changes were reported in heat-treated dairy systems: the disruption of casein micelles and the interaction of whey proteins cause aggregated networks (Asaduzzaman *et al.*, 2021; Zhou, 2026). The existence of the micropores and the fractures indicate dehydration and contraction of the structure, and this could depend on the textural properties and ingredient functionality. These properties reveal that Chobogo is not a lifeless residue but a structurally dynamic resource that can be applied in food formulation.

The ratio of the high dry matter content (90.99 g/100 g) to the energy density (620 kcal/100 g) suggests that the milk solids were significantly concentrated during processing when compared to other dairy products. Other dairy systems that were exposed to thermal concentration have shown similar gains in nutrition (Bador *et al.*, 2024). These energy-dense meals have historically been crucial in meeting the high physical needs of nomadic people, even if modest consumption is

necessary due to their high fat content. Notably, the presence of residual proteins and minerals shows that Chobogo preserved vital nutritional components throughout processing rather than losing them.

This interpretation has also been confirmed by the amino acid profile, which revealed that all essential amino acids are present, with the highest amount of leucine. The maintenance of amino acid diversity without a significant adverse effect on protein quality shows that thermal treatment did not cause a severe adverse effect on protein quality. It aligns with earlier research that indicated that in controlled conditions, protein digestibility may be preserved (or even increased) by heat processing (Rehman *et al.*, 2023). Furthermore, the availability of glutamic and aspartic acids could also be used to enhance flavor due to umami perception, which further adds value to the product. Saturated fatty acids, especially palmitic and stearic acids, dominated the fatty acid composition of Chobogo, and it is characteristic of dairy. Nonetheless, a more balanced lipid profile due to the presence of monounsaturated fatty acids, particularly oleic acid, has potential cardioprotective implications (Rehman *et al.*, 2023). Fatty acids like butyric acid are also short-chain fatty acids that might promote gut health and metabolic processes. The ratio of omega-6/omega-3 (5.94) is not too high or too low, which indicates a balance that is acceptable in nutrition (Rehman *et al.*, 2023).

Dairy byproduct valorization is an idea that puts its portions to functional use to minimize wastage and maximize economic and nutritional potential (Adersa *et al.*, 2021). In that sense, Chobogo is a culturally grounded example of innate circularity, where the olden-day practices were already in line with the present principles of sustainability. The study is, however, constrained by the fact that it concentrates on one batch of production from the Kyrgyz Republic, which does not allow the researcher to evaluate variability of a product with relationship to the quality of the raw materials, season of the year, or processing environment. These dimensions, as well as digestibility, shelf-life stability, and how they can be used in food product development, should be investigated in the future.

## CONCLUSION

This paper repositions the Kyrgyz Chobogo as an ignored dairy residue as a resource into already circular food systems, highlighting how Kyrgyz Chobogo can be a useful dairy byproduct by being valued as a highly sustainable, value-added product. The results of the comprehensive physicochemical, nutritional, and structural analysis permit concluding that Chobogo still has a high percentage of milk-derived nutrients, and its characteristics are characteristic of a functional and energy-rich food matrix. The increased overall solids content and the high energy value show its value as a concentrated nutritional product; the fact that the product contains essential amino acids attests to how the quality of the proteins was not lost by the use of a very intensive thermal treatment. Besides, the saturated and unsaturated lipid ratio, which is encoded in the fatty acid profile, justifies its applicability in energy sources and its possible application in diets. Microstructural analyses also reveal that the Chobogo has a complex and porous matrix, which could affect its functional behaviour in food systems. Concerning sustainability, these findings underscore the fact that Chobogo is not a worthless byproduct but a rich nutrient

fraction that can be successfully reused in the food chain. Circular principles can be applied naturally to its traditional production; minimal waste is produced, and every component of milk is used. This is in line with contemporary developments in global movements towards more resource-efficient resource use and minimization of losses of the food system. Nevertheless, the paper is constrained by the fact that only one production batch was used, and future studies should consider variability under various production parameters, in addition to its shelf life, digestibility, and acceptability by different populations at large. Standardization of processing guidelines and safety measures will be crucial in ensuring that it can be transferred out of domestic usage and into more extensive industrial or commercial usage. To sum up, Chobogo is an illustrative case of the use of traditional knowledge and practice in contemporary sustainable food strategies. Its valorisation can provide the way to reconcile cultural legacy with modern innovativeness, which will lead to the creation of resource-saving, nutritious, and eco-friendly dairy systems.

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