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Evaluation of butter produced from whey and milk fat in terms of some quality criteria and fatty acid compositions

Evaluación de mantequilla producida a partir de suero y grasa láctea en términos de algunos criterios de calidad y composición de ácidos grasos

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ABSTRACT

Whey is a dairy product that was formed as a result of cheese making and is considered a dairy residue or by–product. Making the best use of whey is important in terms of protecting the environment, preventing economic losses and gaining added value. The aim of this study was to obtain butter, an economical and healthy product from whey, and to compare butter obtained from milk in terms of fatty acid profile, color values and some chemical quality criteria. In addition, it is to determine the butter yield of whey. For this purpose, butter was produced from raw cow's milk and from whey in accordance with the technology. Dry matter (%), ash (%), fat (%), pH, titration acidity and refractive index to determine chemical quality, color analysis with digital colorimeter to determine color values and fatty acid analysis with GC–FID to determine fatty acid profile done. It was determined that butters produced from milk and whey were not statistically different (*P*>0.05) in terms of other chemical properties except the fat content they contain. In terms of color values and fatty acid profiles, it was determined that butter produced from milk and whey cheese had similar values. In the butter samples, palmitic and myristic acids were the most common fatty acids. The butter yield of whey was determined as 405 g butter·100 L^{-1}. Thus, it was concluded that whey, which is an important milk residue, can be used as an alternative raw material in the production of butter and that producing butter from whey will contribute to the economy and protection of the environment.

Key words: Butter; fatty acid; milk; whey

RESUMEN

El suero es un producto lácteo que se forma como resultado de la elaboración del queso y se considera un residuo o subproducto lácteo. Hacer el mejor uso del suero es importante en términos de protección del medio ambiente, evitando pérdidas económicas y ganando valor agregado. El objetivo de este estudio fue obtener mantequilla, un producto económico y saludable a partir del suero de leche, y comparar la mantequilla obtenida de la leche en términos de perfil de ácidos grasos, valores de color y algunos criterios químicos de calidad. Además, es para determinar el rendimiento de mantequilla de suero. Para ello, se producía mantequilla a partir de leche cruda de vaca y suero de acuerdo con la tecnología. Materia seca (%), ceniza (%), grasa (%), pH, titulación de acidez e índice de refracción para determinar la calidad química, análisis de color con colorímetro digital para determinar valores de color y análisis de ácidos grasos con GC–FID para determinar el perfil de ácidos grasos hecho. Se determinó que las mantequillas producidas a partir de leche y suero no fueron estadísticamente diferentes (*P*>0,05) en cuanto a otras propiedades químicas excepto el contenido de grasa que contienen. En términos de valores de color y perfiles de ácidos grasos, se determinó que la mantequilla producida a partir de leche y queso de suero tenían valores similares. En las muestras de mantequilla, el ácido palmítico y mirístico fueron los ácidos grasos más comunes. El rendimiento de mantequilla del suero se determinó en 405 g de mantequilla·100 L^{-1}. Por lo tanto, se concluyó que el suero, que es un importante de leche, se puede utilizar como materia prima alternativa en la producción de mantequilla y que la producción de mantequilla a partir del suero contribuir a la economía y protección del medio ambiente.

Palabras clave: Mantequilla; acido graso; leche; suero

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INTRODUCTION

Whey is a dairy product that is formed as a result of cheese making and is considered a dairy residue or dairy by–product. During cheese production, it is the watery part that remains after the milk is coagulated by acid or proteolytic enzymes and separated from the curd [1]. Approximately 85% of the milk used in cheese making is whey. Whey appears yellowish–green in color due to the riboflavin it contains [2]. Its composition varies depending on the type of cheese produced or the casein production method used. Whey contains various bioactive minor proteins, mainly lactose, a small amount of fat, mineral substances and vitamins [3]. For this reason, whey is important in terms of nutrition. However, whey is generally thrown into the environment, not a nutritional product. Considering the annual total amount of milk produced in the World; it is reported that whey thrown into the environment can meet the protein needs of approximately one million people [4].

Whey can be used in animal feeding and food industry. It can be used especially in the food industry, in areas such as yogurt, ice cream, chocolate, mayonnaise, confectionery products, bakery products, sausage type meat products, salad dressings, soft drinks, edible film–coated packaging materials [5]. It has also been reported that whey has many benefits for human health. It can also be used in the pharmaceutical industry and in various applications for therapeutic purposes [6, 7].

As a result of cheese production in Türkiye, approximately two million tons·year^{-1}, in the World approximately 180 to 190 million tons·year^{-1} whey is produced. However, a small part of the released whey is used in the production of curd cheese and whey powder, while a significant part is left as waste to the environment without being evaluated [8]. Organic substances in whey, which is thrown into the environment without any treatment, undergo fermentation and cause serious environmental pollution [9]. Whey is a by product of producing cheese and is frequently found in food products like protein powders and sports supplements. However, the discharge of whey into the environment can harm the ecosystem.

The effect on water resources is one of the key environmental issues connected to the production of whey. The release of contaminants into surface and ground waterways results from the huge volume of effluent generated by the treatment of whey wastewater, which can be difficult to handle [10]. Untreated whey wastewater discharge is thought to be capable of releasing significant amounts of nutrients including nitrogen and phosphorus, which can lead to eutrophication and the development of toxic algal blooms [11]. The emission of greenhouse gases (GHG) from the manufacturing of whey is a further issue. As a consequence of anaerobic digestion, the treatment of whey wastewater produces methane, a strong greenhouse gas [12]. According to estimates, producing one ton of cheese results in the production of 6.5 tons of CO_2 equivalent [13].

Whey production also produces a lot of solid waste, like cheese curds, which can be troublesome to dispose of and pollute the environment. An estimated 0.5 tons of solid waste are produced during the manufacture of one ton of cheese [14]. Methane, a potent greenhouse gas (GHG) produced as a byproduct of anaerobic digestion, is released into surface and ground waters as a result of the hard, large volume of effluent created by the treatment of whey wastewater. Whey production also generates a significant amount of solid waste that could be difficult to dispose of and harm the environment.

When the usage areas of whey and the studies are examined, it is concluded that it can be evaluated by concentrating, fermenting and obtaining by–products by using more advanced technologies, as well as direct usage areas. Making the best use of whey is important in terms of protecting the environment, preventing economic losses and gaining added value.

Fatty acids contained in milk and dairy products are important for human health because of their preventive and therapeutic properties. Fatty acids are also important in determining the composition and quality of dairy products [15]. Therefore, it is important to determine the fatty acid content of dairy products. The physical, chemical and physiological properties of butter, which is one of the dairy products, primarily depend on the type and amount of fatty acids in its structure. The carbon number of fatty acids, the degree of unsaturation and the positional distribution of fatty acids in triglycerides affect the nutritional and physical properties of butter [16]. Having a lot of fatty acids with a low melting point in butter softens the fat. The high melting point fatty acids also harden the butter. Unlike vegetable oils, butter contains glycerides of low molecular fatty acids such as butyric acid, caproic acid and caprylic acid, as well as other fatty acids. By determining such various fatty acids, the quality of the butter and whether the butter is cheated can be determined.

The aim of this study was to obtain butter from whey, which is an economical and healthy product, and to compare butter obtained from milk in terms of fatty acid profile, color values and some chemical quality criteria. In addition, the other purpose of this study was to determine the fat yield of whey.

MATERIALS AND METHODS

The milk used in the research was purchased from a dairy farm in Şanlıurfa Province. A total of 255 L of milk purchased, hygienically milked by the owner of the farm with a milk machine, was brought to the Harran University Veterinary Faculty Food Hygiene and Technology laboratory in the cold chain, and production started immediately. First of all, cheese was made from 200 L milk to obtain whey, and filtration was performed to completely separate the whey from the curd (FIG. 1). Later, butter was produced from the obtained whey and the remaining milk. After the production process, fatty acid analyzes were made from raw milk, butter obtained from milk and butter obtained from whey. Some chemical (Dry matter (%), ash (%), fat determination (%), pH, titration acidity (% lactic acid) and refractive index) analyzes were performed on the butter samples. In addition, butter yield of whey was determined.

Production of butter from whey and milk

Raw cow's milk (50 L) and whey (170 L) were heated (MTOPS, MS2024, Kore) to approximately 37 °C and the creams were separated in a milk cream machine (Asya Zenit–GA–140, Türkiye). The obtained creams were whey–turized (1 min at 95 °C). Afterwards, the creams were cooled (Arçelik, 583650 EB, Türkiye) and allowed to mature at room temperature of 20–25 °C until pH reached 5.0–5.2 pH (HI, 11310, Hanna Instruments, USA). After the ripening process, the creams were transferred to the churning machine (Şahbaz, Type–1060, Türkiye). By adding water as much as the amount of cream obtained, the churning process was carried out at 18 ± 2 °C for 35 min. In order to collect the granules of the butter formed after clarification and completely separate it from the buttermilk, it was washed 3 times with water.

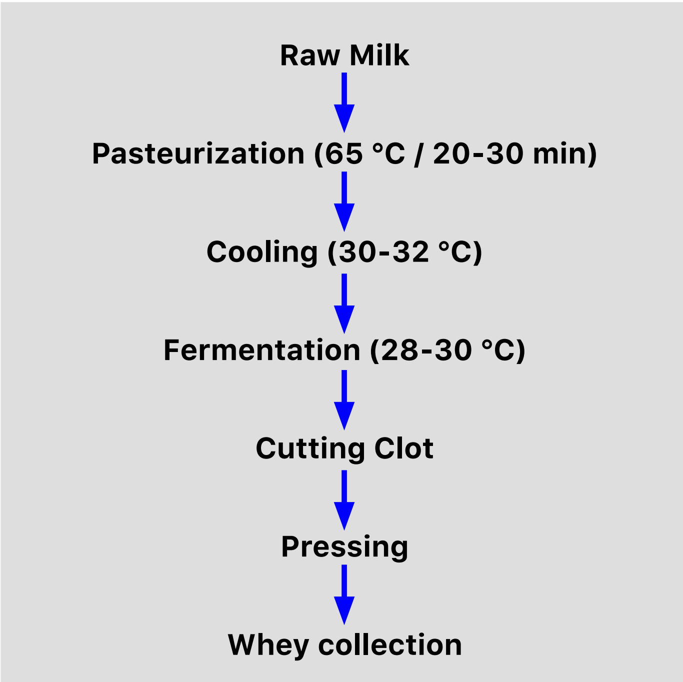

FIGURE 1. Whey production scheme

Then, the obtained butters were taken into 50 mL falcon tubes and stored (Arçelik, 2501 F, Türkiye) at -8 °C in the dark until analysis.

Determination of fatty acid profile

For the lipid extraction process, firstly, the samples were taken into 50 mL centrifuge (CLS Scientific, CLMC-1508, Türkiye) tubes and weighed (Desis, THB 300, Türkiye). 38 mL of milk and whey samples and 10 g of butter and cream samples were taken and homogenized by mixing (IKA, T 25 digital ULTRA-TURRAX®, Germany) with 28 mL of distilled water. Butter samples were thoroughly melted in a water bath (ISOLAB, 602.02.001, Germany) at about 50 °C before being homogenized. All samples were homogenized for 2 min in a homogenizer (IKA, T 25 digital ULTRA-TURRAX®, Germany). Afterwards, the samples were centrifuged at 4 °C for 30 min at 17.800 × g. After centrifugation, the tubes were placed on ice and the fat layer was collected on top, and the fat layer was transferred to another tube and the extraction stage was completed. 2 g of the lipid extracts were taken, dissolved in 10 mL of hexane, 0.5 mL of 2 N KOH-methanol solution (Sigma-Aldrich Co. USA) was added, shaken in a vortex (Dlab, MX-S, China) and kept in the dark for 1 hour. For the separation of fatty acid methyl esters in the standards and samples, 0.5µL injections were made into the gas chromatography (Shimadzu, GCMS-QP2020 NX, Japan). FID detector and capillary column (Technochroma TR882192 TR-CN 100 (100 mm × 0.25 mm × 0.20µm)) were used for the determination of fatty acids. The samples, which were kept at 80 °C, which is the initial temperature, for 2 min, were kept at 150 °C for 2 min with an increase rate of 5 °C per min, and then a temperature of 190 °C was reached with an increase of 2 °C per min. The flow rate was 0.7 $mL \cdot min^{-1}$, the injection block temperature was 230 °C and the detector temperature (J&W Scientific, Folsom, CA, USA) was 240 °C. The peaks obtained from the samples were defined by comparison with the standard peaks and fatty acids were calculated as % of the sum of the concentrations of the defined peaks [17].

Chemical analysis

For the determination of dry matter, approximately 5 g of sample was weighed into glass dry matter containers with lids brought to constant weight and dried in a drying cabinet at 105 °C until constant weight was reached. Results are given in % [18]. For ash determination, approximately 5 g of sample was weighed into porcelain crucibles and dried in a drying cabinet at 550 °C until constant weight. Results are given in % [18]. For pH determination, measurements were made using a pH meter (HI 11310, Hanna Instruments, USA) [18]. For the determination of acidity, 5 g butter sample was mixed with 40 mL of alcohol-ether (Sigma-Aldrich Co. USA) in 1:1 volume and homogenized. After adding one or two drops of 1% phenolphthalein (Sigma-Aldrich Co. USA), it was titrated with 0.25 N NaOH until pink color. The result was found by multiplying the amount of NaOH (Sigma-Aldrich Co. USA), spent in titration by 5 [19]. For fat determination, 5 g of butter sample was taken, put into the butter butyrometer goblet (İLDAM, 01-249, Türkiye) and 10 mL (d=1.55) H2SO4 (Sigma-Aldrich Co. USA) was added to melt the butter. After melting, 5 mL of water and 1 mL of amyl-alcohol (Sigma-Aldrich Co. USA) were added and mixed. Afterwards, it was centrifuged for 5 min in a gerber centrifuge (1350 rpm-350 g, 8 Goddes, maximum 65 °C, external dimension (mm) 470 × 380 × 250) and the result was expressed as % [19]. The refractive indexes of butter samples were measured with the help of a refractometer (OPTIKA, 2WAJ, Italy) connected to a water bath (Thermo, GP 02, USA) set at 40 °C [20].

Color analysis

Color measurement of butter samples was made with CS-10° 8 mm portable digital colorimeter (CHNSpec, Hangzhou, China). Before measuring, the color instrument was calibrated with standard white r tiles. L* (brightness), b* (yellow-blue), and a* (red-green) color coordinates were determined according to the CIELab color scale [21]. Measurements were made from 3 different points on the surface of each standard volume/size butter sample and the results were recorded.

Calculation of butter yield

Butter yield was typically calculated as a percentage of the total weight of milk or cream used to make butter. The method for calculating butter yield from milk and whey was as follows:

1. The weight of milk or cream to be used to make butter was measured.
2. After separating the butter from the buttermilk, the butter and buttermilk were weighed.
3. The weight of the butter was then divided by the weight of the original milk/whey or cream and multiplied by 100 to express the result as a percentage.
4. Butter yield was calculated by the formula: (Butter Weight / Milk or Whey Weight) × 100

Statistical analyzes

t test analysis was used in the analysis of the data and Duncan test was used for pairwise comparison of groups with significant difference. SPSS (version 21.0) package program was used in the calculations.

RESULTS AND DISCUSSION

The results of the chemical analysis of butter produced from milk and whey are given in TABLE I. It was determined that there was no statistical difference (P>0.05) in terms of other chemical properties except the fat content of the butter produced from milk and whey. The fat ratio of butter produced from milk was determined as 81.55±1.14%, and the fat ratio of butter produced from whey was determined as 78.75±1.06%.

TABLE I
Chemical analysis

	Milk butter	PAS butter
Dry matter (%)	83.27±0.13^a	82.58±0.49^a
Ash (%)	0.21±0.03^a	0.18±0.01^a
Fat (%)	81.55±1.14^a	78.75±1.06^b
Titration acidity (%)	0.43±0.05^a	0.37±0.06^a
pH	4.31±0.25^a	4.02±0.26^a
Refractive index	1.4570±0.0014^a	1.4535±0.0021^a

$^{a-b}$: Mean values with different letters in the same column are significantly different (P<0.05)

As a result of the analysis, the fatty acid contents of butter produced from milk and whey are given in TABLE II. The chromatograms of the fatty acid contents obtained in the GC–FID device in the samples are given in FİG. 2.

TABLE II
Fatty acids and their amounts determined in the samples

Fatty acid type	Retention time	Milk sample	Milk butter sample	Whey butter sample
$C_{4:0}$ (butyric acid)	11,169	4,29± 0,57^a	4,08± 0,22^a	2,45± 0,20^b
$C_{6:0}$ (caproic acid)	12,858	3,18±0,21^a	2,64±0,10^b	2,23±0,13^b
$C_{8:0}$ (caprylic acid)	15,778	2,09±0,12^a	1,65±0,10^b	1,48±0,11^b
$C_{10:0}$ (capric acid)	19,757	4,39±0,14^a	3,64±0,07^b	3,54±0,10^b
$C_{11:0}$ s(undecanoic acid)	21,705	0,43±0,06^a	0,34±0,05^a	–
$C_{12:0}$ (lauric acid)	24,046	5,46±0,14^a	4,56±0,01^b	4,61±0,07^b
$C_{13:0}$ (tridecanoic acid)	26,118	0,31±0,02	–	–
$C_{14:0}$ (myristic acid)	28,144	16,46±0,44^a	14,07±0,31^b	12,26±0,26^c
$C_{14:1}$ (myristoleic acid)	29,658	1,86±0,12^a	1,49±0,62^a	1,79±0,13^a
$C_{15:0}$ (pentadecanoic acid)	30,036	1,18±0,09	–	–
$C_{16:0}$ (palmitic acid)	31,949	35,80±0,96^a	35,52±0,82^a	35,60±0,54^a
$C_{16:1}$ (palmitoleic acid)	33,123	1,76±0,08^a	1,59±0,04^a	1,63±0,02^a
$C_{18:0}$ (stearic acid)	35,458	5,54±0,13^a	4,52±0,03^b	3,63±0,11^c
$C_{18:1n9c}$ (cis–oleic acid)	36,496	16,89±0,46^a	16,79±0,31^a	16,48±0,21^a
$C_{18:2n6c}$ (cis–linoleic acid)	38,051	1,17±0,34^c	3,27±0,64^b	10,32±0,13^a
$C_{23:0}$ (tricosanoic acid)	43,758	–	2,67±0,05^a	2,47±0,05^a
$C_{24:1}$ (nervonic aid)	48,025	0,08±0,01^c	3,13±0,08^a	1,43±0,10^b

$^{a-b}$: Mean values with different letters in the same column are significantly different (P<0.05)

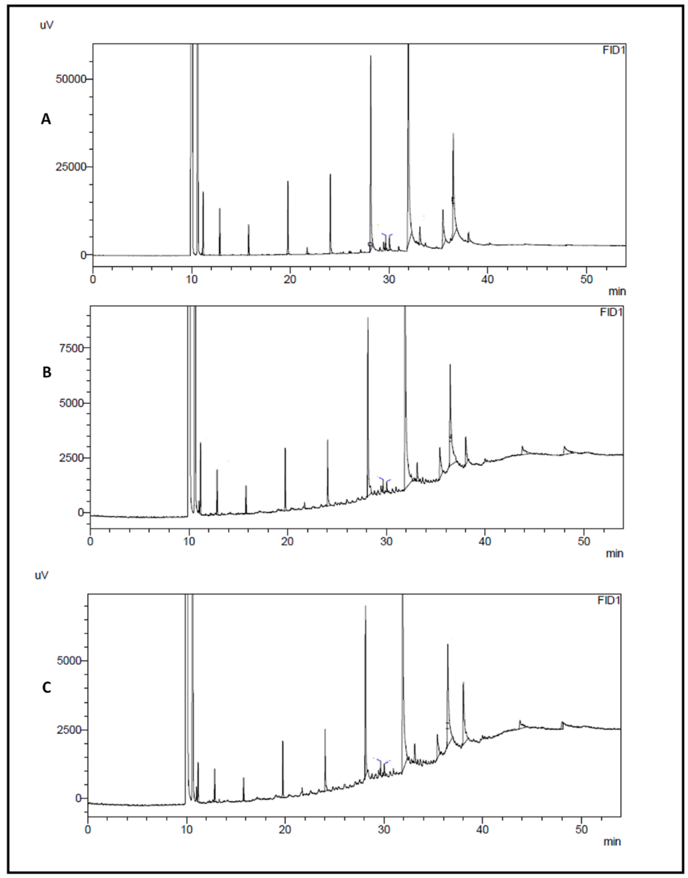

FIGURE 2. Fatty acid chromatograms of the samples. A: Milk sample B: Milk butter sample C: Whey butter sample

Fat content is important in butter. It was seen that there are few differences between the results of the chemical properties of butter samples of this study and other studies [22, 23, 24, 25, 26]. In a study conducted by Kasapcopur [24], it was reported that the fat content of butter samples produced from creams obtained from whey samples was between 78.23–79.97%. It was not surprising that there are small differences between studies because the composition of milk and whey, cheese and butter production processes strongly affect butter composition [24, 27]. In this study, butter yield of whey was determined as 28.57±1.18 kg of cheese and 171.42±2.34 L of whey were obtained from 200 L milk used for cheese making. 1,530±0.08 mL of cream was obtained from 170 L of whey used for butter production. From this cream, 688.5±0.04 g butter was obtained. If expressed as a percentage, it means that 405±0.03 g butter was obtained from 100 L Whey. Costa *et al.* [28] reported that approximately 5 kg of butter was obtained from 1,000 L of whey, similar to the results of the current study. It should be noted that yield may vary depending on factors such as the quality of the milk/whey or cream used, the butter production method, and the temperature and timing of the process.

The fatty acid composition of butter is particularly important in determining its physical, chemical, and nutritional properties. Although milk fat contains about 400 fatty acids, the vast majority of these fatty acids are only present in trace amounts [29]. In this study, palmitic, stearic, myristic, lauric, and cis–oleic acids were the most common fatty acids, while other fatty acids were found in trace amounts in butter samples. It has also been reported by other researchers that the most common fatty acids in butter are palmitic, stearic, and myristic acids [23, 24, 25, 26, 30]. Stearic and myristic acids were found to be higher in milk-derived butter (TABLE II). In addition, butyric and nervonic acids were found to be higher in milk-derived butter (TABLE II). It was determined that cis-linoleic acid was higher in whey-derived butter. While undecanoic acid was detected in milk and butter obtained from milk, it was not detected in butter obtained in whey. Pentadecanoic and tridecanoic acid were detected in milk, but not in butter samples. In terms of other fatty acids, milk and butter obtained in whey were found to have similar values. It was seen that there are few differences between the results of this study and the results reported in the fatty acid contents of the butter samples [22, 24, 26]. It was thought that this situation arises from factors such as the composition of the raw material milk and whey used in butter production, the fat ratio of the cream, the method of making butter and the production period [26, 27].

As a result of the analysis, the color values of the butter samples produced from milk and whey are given in TABLE II. It was determined that the use of milk and whey in butter production was not effective on color parameters ($P>0.05$). Özen [25]. reported that the L*, a*, b* value of butter produced from milk cream was 86.12, -2.51, 19.31, respectively, and the L*, a*, b* value of butter produced from whey cream was 85.81, -2.54, 19.81, respectively.

TABLE III
Color values of butter samples

Color parameter	Milk butter	Whey butter
L*	83,19 ± 0,86	84,21 ± 0,93
a*	-2,95 ± 0,89	-2,90 ± 0,39
b*	10,84 ± 0,33	10,22 ± 0,40

L* (brightness), b* (yellow–blue), a* (red–green)

Kasapcopur [23] reported that the L*, a*, b* values of butter produced from 4 different whey were 83.01–86.76, -1.01/-1.56 and 15.92–17.72, respectively. There are slight differences between the color values determined in the current study and the color values reported in previous studies [31, 32]. It was thought that this situation is due to the different compositions of the milk used in the studies and the differences in the production technology of the cheese from which the whey is obtained. Butter samples from the East Black sea Region of Türkiye were lighter (78.49), redder (-1.3), and yellower (24.74) than the samples analyzed in the current study. One possible comment for these results is that the feeds in that region may embody higher amounts of β-carotene [33].

CONCLUSIONS

As a result, it was determined that butter produced from whey was similar to butter produced from milk in terms of chemical properties, color value and fatty acid composition. In addition, it was determined that the fat yield of whey was at a substantial level. Thus, it has been concluded that whey, which is an important dairy industry residue, can be used as an alternative raw material in butter production and the production of butter from whey will contribute to the economy and environmental protection. Advantages of obtaining butter from whey:

1. By-product use: Whey, a by-product of the cheesemaking process, can be converted into butter, allowing a product that would otherwise be discarded to be used.
2. Increased economic value: By converting whey into a high value product such as butter, obtaining butter from whey can increase the economic value of whey.
3. Increased protein and mineral content: The high protein and mineral content of whey makes butter made from it a product with important nutritional value.
4. Minimized environmental impact: Since whey treatment generates a large amount of waste, it can be difficult to dispose of and can have a negative impact on the environment.
5. Improved food safety: Whey is pasteurized before butter production, this improves food safety and reduces the risk of contamination by pathogenic microorganisms.
6. Reducing land use: Making butter from whey reduces the amount of land required to raise animals that are beneficial for the environment.

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Conflict of interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article

BIBLIOGRAPHIC REFERENCES

[1] Tribst AAL, Falcade LTP, Carvalho NS, Júnior BRDCL, de Oliveira MM. Manufacture of a fermented dairy product using whey from sheep's milk cheese: An alternative to using the main by-product of sheep's milk cheese production in small farms. Intern. Dairy J. [Internet]. 2020; 111:104833. doi: https://doi.org/mddm

[2] Garg L, Kumar K. Industrial applications of whey. Pharma. [Internet]. 2021 [cited 25 April 2023]; 10(2):387–390. Available in: https://bit.ly/4b4jPyW

[3] Minj S, Anand S. Whey proteins and its derivatives: Bioactivity, functionality, and current applications. Dairy. [Internet]. 2020; 1(3):233–258. doi: https://doi.org/mddn

[4] Sirmacekic E, Atilgan A, Rolbiecki R, Jagosz B, Rolbiecki S, Gokdogan O. Kocięcka J. Possibilities of Using Whey Wastes in Agriculture: Case of Turkey. Energies. [Internet]. 2022; 15(24):9636. doi: https://doi.org/mddp

[5] Yüksel M, Yüksel AK, Ürüşan H. [Various Properties of Whey and Possibilities of Its Utilisation]. KSÜ Müh. Bil. Derg. [Internet]. 2019; 22(3):114–125. Turkish. doi: https://doi.org/mddr

[6] Rocha-Mendoza D, Kosmerl E, Krentz A, Zhang L, Badiger S, Miyagusuku-Cruzado G, García-Cano I. Invited review: Acid whey trends and health benefits. J. Dairy Sci. [Internet]. 2021; 104(2):1262–1275. doi: https://doi.org/mdds

[7] Ren S, Jiménez-Flores R, Giusti MM. The interactions between anthocyanin and whey protein: A review. Compr. Rev. Food Sci. Food Saf. [Internet]. 2021; 20(6):5992–6011. doi: https://doi.org/mddt

[8] Türkmen N, Akal C, Koçak C. [Some Properties of Ayran Samples Produced with Different Ratios of Whey]. Akademik Gıda. [Internet]. 2017; 15(3):256–260. Turkish. https://doi.org/mddv

[9] Zandona E, Blažić M, Režek-Jambrak A. Whey utilization: Sustainable uses and environmental approach. Food Technol. Biotechnol. [Internet]. 2021; 59(2):147–161. doi: https://doi.org/mddw

[10] Chen GQ, Talebi S, Gras SL, Weeks M, Kentish SE. A review of salty waste stream management in the Australian dairy industry. J. Environ. Manage. [Internet]. 2018; 224:406–413. doi: https://doi.org/gd98gc

[11] Nayyar D, Nawaz T, Noore S, Singh AP. Food Processing Wastewater Treatment: Current Practices and Future Challenges. In: Singh SP, Rathinam K, Gupta T, Agrawal AK, editors. Pollution Control Technologies. Energy, Environment, and Sustainability [Internet]. Singapore: Springer; 2021. p. 177–208. doi: https://doi.org/mddx

[12] Fang YR, Li S, Zhang Y, Xie GH. Spatio-temporal distribution of sewage sludge, its methane production potential, and a greenhouse gas emissions analysis. J. Clean. Prod. [Internet]. 2019; 238:117895. doi: https://doi.org/mddz

[13] Berlese M, Corazzin M, Bovolenta S. Environmental sustainability assessment of buffalo mozzarella cheese production chain: A scenario analysis. J. Clean. Prod. [Internet]. 2019; 238:117922. doi: https://doi.org/mdd7

[14] Pandey A, Srivastava S, Rai P, Duke M. Cheese whey to biohydrogen and useful organic acids: A non-pathogenic microbial treatment by *L. acidophilus*. Sci. Rep. [Internet]. 2019; 9:8320. doi: https://doi.org/gf7c3g

[15] Kahraman M, Yüceer-Özkul B. [Investigation of Milk Fatty Acid Profiles in Some Native and Crossbred Sheep Genotypes]. Harran Üniv. Vet. Fak. Derg. [Internet]. 2020; 9(2):126–132. Turkish. doi: https://doi.org/mdd9

[16] Garau V, Manis C, Scano P, Caboni P. Compositional characteristics of mediterranean buffalo milk and whey. Dairy. [Internet]. 2021; 2(3):469–488. doi: https://doi.org/mdfc

[17] Daş A, Kahraman M, Güngören G, Daş B, Boyraz, MÜ. Milk yield and milk quality characteristics of Awassi sheep under semi-ıntensive conditions. J. Adv. VetBio. Sci. Tech. [Internet]. 2022; 7(1):62–71. doi: https://doi.org/mdfd

[18] International Union of Pure and Applied Chemistry (IUPAC). In: Paquot C, Hautfenne A, editors. Standard methods for analysis of oils, fats and derivatives. 7th. ed. Oxford, UK: Blackwell Scientific; 1987; p. 1–151.

[19] Metin M. Süt ve Mamülleri Analiz Yöntemleri. 6th. ed. İzmir, Türkiye: Aegean University Publications; 2012. 439 p.

[20] American Oil Chemist's Society (AOCS). Official Methods and Recommended Practices of the AOCS. 6th. ed. Champaign, IL, USA: AOCS Press; 2009.

[21] Pădureţ S. The effect of fat content and fatty acids composition on color and textural properties of butter. Mol. [Internet]. 2021; 26(15):4565. doi: https://doi.org/mdff

[22] Nadeem M, Mahud A, Imran M, Khalique A. Enhancement of the oxidative stability of whey butter through almond (*Prunus dulcis*) peel extract. J. Food Process. Preserv. [Internet]. 2015; 39(6):591–598. doi: https://doi.org/f773rp

[23] Kasapçopur E. [Determination of quality characteristics of fats produced from whey]. [master's thesis on the Internet]. Kahramanmaraş, Türkiye: Kahramanmaraş Sütçü İmam University; 2016 [cited 10 June 2023]. 72 p. Turkish. Available in: https://bit.ly/3Odzrq4.

[24] Kasapçopur E, Mohammed AM, Colakoglu AS. Effects of differences in whey composition on the physicochemical properties of whey butter. Intern. J. Dairy Technol. [Internet]. 2021; 74(3):535–546. doi: https://doi.org/mdf8

[25] Özen M. Use of creams obtained from milk and whey in butter production. [master's thesis on the Internet]. Burdur, Türkiye: Burdur Mehmet Akif Ersoy University; 2020 [cited 10 June 2023]. 51 p. Available at: https://bit.ly/3Odzrq4.

[26] Çetinkaya A. A Research on Determination of Some Properties of Butter Made from Creams Extracted from Whey and Milk. European J. Agric. Food Sci. [Internet]. 2021; 3(4):19–24. doi: https://doi.org/mdgb

[27] Jinjarak S, Olabi A, Jiménez-Flores R, Walker JH. Sensory, functional, and analytical comparisons of whey butter with other butters. J. Dairy Sci. [Internet]. 2006; 89(77):2428–2440. doi: https://doi.org/cfhcgg

[28] Costa MA, Kuhn D, Rama GR, Lehn DN, Souza CFV de. Whey butter: a promising perspective for the dairy industry. Braz. J. Food Technol. [Internet]. 2022; 25:e2021088. doi: https://doi.org/mdgc

[29] Shahidi F. Edible Oil and Fat Products: Chemistry, Properties, and Health Effects. 6th. Ed. Vol 1. Bailey's Industrial Oil and Fat Products. Hoboken, NJ, USA: Wiley. 2005; p. 1–43.

[30] Aly AH. Fatty acid composition, textural and organoleptic properties of whey butter. J. Food Dairy Sci. [Internet]. 2009; 34(4):3081–3094. doi: https://doi.org/mdgd

[31] Zadow JG. Utilization of milk components: Whey. In: Robinson RK, editor. Modern Dairy Technology. [Internet]. Boston, USA: Springer; 1994 [cited 12 June 2023]. p. 313–373.doi: https://doi.org/dqvg49

[32] Ziarno M, Derewiaka D, Florowska A, Szymańska I. Comparison of the spreadability of butter and butter substitutes. Appl. Sci. [Internet]. 2023; 13(4):2600. doi: https://doi.org/mdgp

[33] Dervisoglu M, Gul O, Guvenc D, Yazici F, Atmaca E, Aksoy A. Evaluation of chemical and microbiological characteristics and fatty acid profiles of butter samples collected from the black sea region of Turkey. Asian J. Chem. [Internet]. 2013; 25(18):10185–10190. doi: https://doi.org/mdgr