Original Article
Food Science and Technology
ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.5327/fst.00309

Physicochemical profile of cream and derivatives obtained from mozzarella and prato cheese whey

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Abstract

Whey is an industrial residue obtained from the production of various cheeses and has the potential to be incorporated into other dairy products. Thus, the objective of the study was to promote whey skimming and standardization and to evaluate the physicochemical characteristics and color parameters of cream, regular butter, buttermilk, and clarified butter produced from whey resulting from the processing of mozzarella and prato cheese. Whey from the processing of mozzarella and prato cheese was skimmed and used for the production of regular butter and clarified butter. The physicochemical parameters and color parameters of whole and skimmed whey, regular and clarified butter, and buttermilk were analyzed. It was observed that whole whey from mozzarella processing had a higher fat proportion compared to prato cheese whey. It was possible to homogenize the whey samples considering the physicochemical parameters. The cream from whey, regardless of whether it resulted from mozzarella or prato cheese whey, only showed differences in color content, which was also the main difference between buttermilk and the regular and clarified butters obtained in this study. The similarities in the physicochemical parameters of regular and clarified butter suggest that these dairy products can be used in whey reutilization.

Keywords: buttermilk; clarified butter; cream; regular butter.

Practical Application: By transforming whey into dairy products such as regular and clarified butter, and buttermilk, companies can reduce industrial waste and increase production efficiency. Furthermore, standardizing and removing fat from whey can enhance the quality of final products, offering consumers diverse options of high-quality dairy products.

1 INTRODUCTION

The conventional manufacturing of cheese involves the release of whey, an aqueous portion, which is considered a residual effluent. This effluent can lead to serious environmental problems due to the increased biochemical/chemical oxygen demand associated with high levels of organic matter. Thus, reutilization has been studied and suggested to improve the economic efficiency of dairies and minimize environmental impacts (Lavelli & Beccalli, 2022).

Whey comprises approximately 85–90% of the milk volume and contains about 55% of the milk nutrients, including 70% lactose (depending on the whey acidity), 14% proteins, 9% minerals, 4% fats, and 3% lactic acid (Blažić et al., 2018; Zandona et al. 2021). The protein fraction of whey represents ~20% of the total milk proteins. It consists of β-lactoglobulin, around 50%, α-lactalbumin, around 20–25%, bovine serum albumin, 10–15%, immunoglobulin, thermo-stable proteose-peptones, and lactoferrin, in smaller proportions, about 1% each fraction (Blažić et al., 2018).

Discarded whey can have acidic or sweet characteristics depending on the processing conditions. The production of most cheeses results in sweet whey with a pH of around 6–7, lower ash content, and higher protein content compared to acid whey. Due to these physicochemical parameters, sweet whey has been studied for utilization in the production of isolated milk protein and lactose recovery (Huffman & Ferreira, 2011), probiotic beverages (Turkmen et al., 2019), and products with pharmaceutical potential, such as peptide isolation (Athira et al., 2021).

The fat content in whey can be an alternative for reutilization of this residue. Fat can be used for the production of food products such as butter. Butter is a complex mixture of

Received 16 Mar., 2024.
Accepted 15 Apr., 2024.
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Conflict of interest: nothing to declare.
Funding: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior–Brasil (CAPES), under Finance Code 001; and Goiano Federal Institute of Education, Science, and Technology, grant number 19/2022.

short- and medium-chain fatty acids, including caproic, caprylic, and butyric acids. Besides containing proteins, butter contains water, minerals, and vitamins A and β-carotene (Salminen et al., 2020).

According to Brazilian legislation, butter is a fatty product obtained exclusively by churning and kneading, with or without biological modification of pasteurized cream derived exclusively from cow's milk, using technologically appropriate processes. The fat content of butter must consist exclusively of milk fat. According to current legislation, the physicochemical parameters that butter must meet are maximum moisture of 16.0%, minimum fat of 82.0% for unsalted butter and not less than 80.0% for salted butter, maximum defatted dry extract of 2.0%, less than 0.5% of carbohydrates (lactose) and proteins, 0.15% ash content, and salt content that may or may not be added, with a maximum of 2% allowed (Brasil, 1996).

Considering the environmental impact that whey can cause and the possibility of incorporating greater economic yield into industries, this study aimed to promote whey skimming and standardization and to evaluate the physicochemical characteristics and color parameters of cream, regular butter, buttermilk, and clarified butter produced from whey resulting from the processing of mozzarella and prato cheese.

2 MATERIALS AND METHODS

2.1 Obtaining whey protein

The refrigerated milk whey used in this experiment was obtained from the cooling tank (3.0°C ± 1.0°C) of a dairy industry located in Rio Verde, GO, Brazil, as a result of processing of mozzarella and prato cheese.

For the collection of milk whey samples, a 50-l polypropylene container was used, previously sanitized with water and neutral detergent, sanitized by immersion in chlorine water at 200 ppm, and rinsed with water at 80.0°C ± 1.0°C. After collection, the raw milk whey was immediately transported to the Laboratory of Animal Products at IF Goiano – Campus Rio Verde, GO, Brazil, filtered, and stored under refrigeration at a temperature of 5.0°C ± 1.0°C until processing.

2.2 Skimming of whey

The milk whey, both resulting from the processing of mozzarella and prato cheese, was skimmed at a temperature of 35°C ± 1.0°C using a cream separator model 36 GR (Casa das Desnatadeiras®), with a capacity of 100.0 l/h. The milk whey underwent skimming twice. After skimming, the milk whey cream was packed into transparent plastic packages (20 cm x 30 cm) and frozen at -20.0°C ± 1.0°C until the physicochemical analyses and butter processing.

2.3 Butter production

For the butter production, the milk whey cream resulting from the processing of mozzarella and prato cheese was used. Homogenization took place in an industrial blender (FAK®) at a ratio of 1:1 water to milk whey cream. The fat was separated from the buttermilk using mechanical force at a temperature of 13.0°C ± 1.0°C. Subsequently, three washes of the butter were carried out at a ratio of 1:6 (butter:water) at a temperature of 10.0°C ± 1.0°C. Then, the mass was subjected to salting with a concentration of 1.5%, packed in polyethylene plastic containers (capacity of 200.0 mL) and previously sanitized (Foschiera, 2004). Then, they were stored at a temperature of 5°C ± 1.0°C until the physicochemical analyses were performed.

2.4 Obtaining buttermilk

The buttermilk resulting from the first wash in the processing of both mozzarella and prato cheese whey butters was pasteurized at a temperature of 72.0°C ± 1.0°C for 20 se and then cooled to a temperature of 42.0°C ± 1.0°C. It was packed into polyethylene plastic containers (capacity of 200.0 mL), previously sanitized and stored at a temperature of 5°C ± 1.0°C until analysis.

2.5 Production of clarified butter

To obtain clarified butter, initially, the same methodology used for producing whey butter was followed, with the addition of a clarification step. This step involved heating the butter to a temperature of 110.0°C ± 1.0°C with stirring until complete melting. The endpoint of heating was considered when the production of bubbles ceased, and the precipitation of the non-greasy solid phase occurred in a dense and opaque form, forming a residue. The supernatant oily liquid phase was separated by filtration and packaged into polyethylene plastic containers (capacity of 200.0 mL), previously sanitized and cleaned. The clarified butter was stored at a temperature of 5°C ± 1.0°C until physicochemical analyses were conducted.

2.6 Physicochemical analysis of whey

The physicochemical composition of the whey was analyzed by near-infrared spectroscopy following the recommendations of the International Organization for Standardization (2013). The somatic cell count (SCC) was determined by flow cytometry according to the International Organization for Standardization (2006) guidelines.

2.7 Physicochemical analysis of dairy derivatives

The fat content was evaluated using the Gerber method according to the standards of the Instituto Adolfo Lutz (2008). The titratable acidity (% lactic acid) and pH were analyzed following method 981.12 of the AOAC (2016). Titratable acidity was determined by titration with 0.1 mol L^{-1} sodium hydroxide solution.

The moisture content of the samples was determined using the official method no. 925.10 of AOAC International (2016). Ash content was determined by total organic matter carbonization in a muffle furnace (Quimis®) according to official method no. 930.05 of AOAC (2016).

For protein analysis, total nitrogen was quantified using the micro-Kjeldahl method as described by AOAC (2016), and a correction factor of 6.38 was considered. Peroxide values were determined using the official AOAC method (2010). Color analysis was performed using a colorimeter (ColorFlex, EZ), with results expressed in L*, a*, and b* values, ΔE*, Chroma, and Hue (Konica Minolta Sensing, 2007; Paucar et al., 2008).

2.8 Statistical analysis

The study was conducted using a completely randomized design, comprising two treatments, three replicates, and triplicate analyses. In this regard, the Sisvar® software (Ferreira, 2011) was used for evaluations, and the data were subjected to analysis of variance (ANOVA). The means comparison was performed using Tukey's test with a probability of $p < 0.05$.

3 RESULTS AND DISCUSSION

The results of the physicochemical composition of whole and skim milk whey are presented in Tables 1 and 2. Regarding the physicochemical composition of whole milk whey from mozzarella and prato cheese, all parameters were similar, except for the fat content, which differed between the whey from mozzarella and prato cheese (Table 1). However, according to Brazilian regulations, both whole milk whey samples can be classified as skimmed (fat content less than 0.5%) (Brasil, 2018). Sodini et al. (2006) reported a fat concentration between 0.3 and 0.4% in sweet whey, which is similar to the values determined in this study. Faucher et al. (2021) found fat levels close to 1.2% for sweet whey from the Parmalat company and described that the fat proportion depends on the presence of prior treatment performed by the industry to ensure effluent disposal.

Regarding skim milk whey, there was only a difference in urea levels between the skim milk whey from mozzarella and prato cheese (Table 2). This difference may be related to the increased proteolytic activity of milk, which can lead to the breakdown of polypeptide chains of proteins and, consequently, the release of urea nitrogen, as well as increased vascular permeability, predisposing the passage of urea molecules from the blood to milk (Santos & Fonseca, 2007). This contamination may prevail in whey. The presence of significantly different values below 10.0 mg/dL of urea nitrogen demonstrates an unbalanced diet in energy and protein provided to lactating animals (Rosa et al., 2012).

It can be observed that the similarities in protein concentration, casein, fat, in the case of skim milk whey, urea, in the case of whole milk whey, lactose, total dry extract, defatted dry extract, and SCC indicate that the whey is similar regardless of whether it is the result of processing mozzarella or prato cheese, and therefore, the processing techniques do not differ regarding the recovery of solid components from raw milk (Huffman & Ferreira, 2011).

Regarding the cream from mozzarella and prato cheese whey, due to the similarities in the physicochemical parameters of the milk whey regardless of the processing, differences were

Table 1. Physicochemical parameters of whole milk whey from mozzarella and prato cheese[1].

Item	Type of whole milk serum	
	Mozzarella	**Prato**
Fat (%)	0.28 ± 0.00a	0.22 ± 0.01b
Protein (%)	1.04 ± 0.01a	1.02 ± 0.01a
Casein (%)	0.69 ± 0.01a	0.68 ± 0.01a
Urea (mg dL^{-1})	21.22 ± 3.27a	17.67 ± 2.59a
Lactose (%)	4.46 ± 0.06a	4.36 ± 0.12a
Total dry extract (%)	6.70 ± 0.05a	6.52 ± 0.13a
Defatted dry extract (%)	6.42 ± 0.05a	6.31 ± 0.12a
Somatic cell count (CS mL^{-1})	10,333.33 ± 2101.58a	11,111.11 ± 2974.17a
Log SCC	3.94 ± 0.09a	3.94 ± 0.07a

[1]Different letters in the rows differ from each other at the 0.05% level according to Tukey's test.

Table 2. Physicochemical parameters of skimmed milk whey from mozzarella and prato cheese[1].

Item	Type of skimmed milk whey	
	Mozzarella	**Prato**
Fat (%)	0.18 ± 0.01a	0.18 ± 0.01a
Protein (%)	1.00 ± 0.02a	0.99 ± 0.01a
Casein (%)	0.64 ± 0.01a	0.65 ± 0.02a
Urea (mg dL^{-1})	29.90 ± 1.16a	23.23 ± 2.41b
Lactose (%)	4.37 ± 0.10a	4.13 ± 0.09a
Total dry extract (%)	6.46 ± 0.08a	6.24 ± 0.11a
Defatted dry extract (%)	6.24 ± 0.08a	6.06 ± 0.09a
Somatic cell count (CS mL^{-1})	13,111.11 ± 4369.86a	7,333.33 ± 2494.44a
Log SCC	3.89 ± 0.16a	3.71 ± 0.13a

[1]Different letters in the rows differ from each other at the 0.05% level according to Tukey's test.

observed only for the instrumental color parameters L*, a*, b*, and Chroma (Table 3). Among the similar parameters, it is worth noting that the titratable acidity did not show any difference. According to Queiroga et al. (2009), the titratable acidity pattern in artisanal creams can be easily modified depending on the count of lactic bacteria present in the environment, contradicting the result found in the samples, demonstrating that the bacterial process is stabilized.

The higher intensity of the luminosity value of the prato cheese whey cream is mainly due to the darker color of this cheese compared to mozzarella cheese, which may result in higher pigments in the whey from this processing and influence other processes (Landin et al., 2021). The a* and b* parameters indicate that the whey cream, regardless of the processing, has a more yellowish color, especially for the prato cheese whey cream, with a higher intensity of this color. Fritzen-Freire et al. (2013) suggest that this difference in the intensity of the yellowish color is due to the presence of riboflavin in the milk. According to Lawless and Heymann (2010), the ΔE* parameter is able to indicate the perception of color parameters of a product by the human eye. Thus, it can be verified that the mozzarella whey cream presented a value less than 1. Martínez-Cervera et al. (2011) described that the values for ΔE* less than 1 indicate that the color difference between the samples cannot be perceptible by the human eye, suggesting that the whey creams would not be differentiated by consumers in terms of color.

Sołowiej et al. (2015) described that the Chroma parameter (C*) represents color saturation, that is, the combination of the parameters a* and b*. With the results obtained for C*, it was possible to observe that the small difference in relation to a* of the mozzarella and prato cheese whey creams was responsible for the difference in this parameter.

The butter from the milk whey resulting from the processing of mozzarella or prato cheese was similar in terms of physicochemical composition and differed only in color parameters, except for luminosity (Table 4). Although there were no differences in the moisture content of the samples, it was possible to observe that the butter processing, considering the steps of churning, kneading, and draining the buttermilk, may have been carried out without the standard required by legislation because they are responsible for reducing the aqueous phase and may increase the moisture content of the final product (Silva et al., 2009). This occurred in this study because according to legislation butter must have a maximum of 16% moisture (Brasil, 1996).

Table 3. Physicochemical parameters and instrumental color parameters of cream from milk whey of mozzarella and prato cheese[1].

Item	Cream from milk whey	
	Mozzarella	Prato
Fat (%)	76.22 ± 1.22a	78.67 ± 0.75a
Protein (%)	1.16 ± 0.14a	1.12 ± 0.12a
Moisture (%)	22.84 ± 0.85a	21.35 ± 1.05a
Ash (%)	0.53 ± 0.06a	0.63 ± 0.05a
pH	3.98 ± 0.03a	4.12 ± 0.02a
Titratable acidity (%)	0.28 ± 0.01a	0.31 ± 0.02a
L*	87.53 ± 0.19b	88.83 ± 0.11a
a*	-0.88 ± 0.01b	0.82 ± 0.12a
b*	14.27 ± 0.17b	19.81 ± 0.29a
Chroma	14.30 ± 0.17b	19.85 ± 0.29a
Hue	-86.41 ± 0.09a	87.92 ± 0.29a

[1]Different letters in the rows differ from each other at the 0.05% level according to Tukey's test.

Table 4. Physicochemical parameters and instrumental color parameters of butter from cream of mozzarella and prato cheese[1].

Item	Butter from milk whey	
	Mozzarella	Prato
Fat (%)	74.44 ± 1.28a	77.33 ± 0.88a
Protein (%)	0.74 ± 0.03a	0.78 ± 0.04a
Moisture (%)	17.27 ± 0.45a	16.59 ± 0.45a
Ash (%)	0.45 ± 0.06a	0.74 ± 0.05a
pH	2.21 ± 0.01a	2.52 ± 0.02a
Titratable acidity (%)	4.29 ± 0.02a	4.10 ± 0.02a
L*	87.21 ± 0.07a	87.45 ± 0.17a
a*	0.90 ± 0.06b	2.97 ± 0.11a
b*	23.00 ± 0.12b	28.02 ± 0.28a
Chroma	23.02 ± 0.12b	28.19 ± 0.29a
Hue	87.77 ± 0.14b	84.08 ± 0.18a
Peroxide index	0.60 ± 0.40a	1.00 ± 0.00a

[1]Different letters in the rows differ from each other at the 0.05% level according to Tukey's test.

All other nutritional values and peroxide index determined are in accordance with the regulations for butter production. Based on the results obtained, dairy industries will not have difficulties in complying with Ordinance No. 146 of 1996 (Brasil, 1996), regardless of the time of year, especially in the hotter seasons, where temperature is a factor contributing to oxidation acceleration, increasing the peroxide index.

The differences in color parameters are related to the fact that butter is produced from the cream resulting from the processing of mozzarella and prato cheese (Table 3). It was observed, once again, that butter produced with the cream resulting from the processing of prato cheese showed a more intense yellowish color.

The buttermilk from common butter was similar in terms of fat, protein, moisture, pH, titratable acidity, and peroxide index, both obtained from butter produced with whey from the processing of mozzarella and prato cheese (Table 5). There were differences only in the ash proportion and the b* parameter.

Machado et al. (2022) reported that buttermilk is the effluent from butter washing and, therefore, carries water-soluble components from the cream, such as minerals, proteins, lactose, whey proteins, and a small fraction of casein, as well as ruptured fat globules in other stages. As the buttermilk in this study refers to butter produced with whey cream from the processing of mozzarella and prato cheese, the differences in ash content are related to the different proportions of water-soluble components of whey from these cheeses (Lavelli & Beccalli, 2022). These soluble proportions may have also contributed to differences in color parameters related to the b* index.

The physicochemical parameters, except for moisture, showed similarity between clarified butter produced with whey cream from the processing of mozzarella and prato cheese (Table 6). There were also differences in color parameters, except for b*.

Brazilian legislation sets a moisture content of 0.2% for clarified butter (Brasil, 1996). However, there are discrepancies regarding the moisture content of clarified butter due to the different processes involved in producing this dairy product. Deosarkar et al. (2016) and Rajorhia (1993) reported that clarified butter may have a maximum moisture content of 0.5%,

Table 5. Physicochemical parameters and instrumental color parameters of buttermilk from regular butter cream of mozzarella and prato cheese[1].

Item	Buttermilk from regular butter	
	Mozzarella	**Prato**
Fat (%)	1.72 ± 0.15a	2.00 ± 0.12a
Protein (%)	0.98 ± 0.18a	1.38 ± 0.27a
Moisture (%)	90.75 ± 0.62a	91.00 ± 0.62a
Ash (%)	0.34 ± 0.02b	0.43 ± 0.03a
pH	6.7 ± 0.01a	6.9 ± 0.01a
Titratable acidity (%)	54 ± 0.01a	58 ± 0.01a
L*	65.47 ± 0.46a	64.67 ± 0.10a
a*	-1.84 ± 0.01a	-1.80 ± 0.02a
b*	-0.67 ± 0.11b	1.21 ± 0.04a
Chroma	2.14 ± 0.04a	2.20 ± 0.03a
Hue	16.26 ± 2.84b	-33.46 ± 1.21a
Peroxide index	0.50 ± 0.10a	0.26 ± 0.07a

[1]Different letters in the rows differ from each other at the 0.05% level according to Tukey's test.

Table 6. Physicochemical parameters and instrumental color parameters of clarified butter from cream of mozzarella and prato cheese[1].

Item	Clarified butter	
	Mozzarella	**Prato**
Fat (%)	91.55 ± 0.68a	90.88 ± 0.93a
Protein (%)	0.82 ± 0.06a	0.90 ± 0.07a
Moisture (%)	0.48 ± 0.03a	0.38 ± 0.03b
Ash (%)	0.34 ± 0.01a	0.32 ± 0.01a
pH	0.21 ± 0.01a	0.25 ± 0.03a
Titratable acidity (%)	0.89 ± 0.02a	0.94 ± 0.01a
L*	2.95 ± 0.06b	3.47 ± 0.04a
a*	-0.21 ± 0.03b	0.05 ± 0.02a
b*	4.20 ± 0.05a	4.06 ± 0.06a
Chroma	4.21 ± 0.05b	4.06 ± 0.06a
Hue	-33.28 ± 9.58b	15.88 ± 10.37a
Peroxide index	0.60 ± 0.11a	0.27 ± 0.07a

[1]Different letters in the rows differ from each other at the 0.05% level according to Tukey's test.

and in this case, the moisture content of the clarified butters produced in this study would be within the expected standard.

Regarding the fat content, there were no significant differences between the different types of clarified butter from mozzarella and prato cheese whey, but they were below the established 98.5% lipid content (Brasil, 2007), probably due to the low temperature in the cooking process and the higher moisture content of the samples. The processing technique may also have influenced the butter composition, as evidenced by the significant difference in total dry extract between the two production treatments.

As for the instrumental color parameters (L*, a*, Chroma, and Hue), the values obtained for the L* coordinate were 2.95 for clarified butter from mozzarella cheese whey and 3.47 for clarified butter from prato cheese whey, with the butter produced from mozzarella whey showing a lower value. This may indicate that this cheese has lower pigment proportions, resulting in clearer whey. This same fact may have influenced the differences in colors regarding the a* coordinate and, consequently, the values of Chroma and Hue.

4 CONCLUSIONS

Differences in fat content were observed between whole milk whey from mozzarella cheese and whole milk whey from prato cheese. However, it was noted that these differences did not influence physicochemical differences in the production of regular butter and clarified butter.

The urea results in skimmed mozzarella cheese whey and skimmed prato cheese whey showed differences. The values demonstrated an unbalanced diet in terms of energy and protein offered to lactating animals.

There were color differences among regular butter, clarified butter, and buttermilk produced from whey from the processing of mozzarella and prato cheese. However, the similarities in the physicochemical parameters of these products suggest that dairy products can be utilized in whey reuse.

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