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REVIEW ARTICLE

Whey butter: a promising perspective for the dairy industry

Manteiga de soro de queijo: uma perspectiva promissora para as indústrias lácteas

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Abstract

Cheese whey is the main by-product obtained in the production of cheese. Despite its high nutritional value, approximately half of the whey volume generated is still disposed incorrectly, which causes damage to the ecosystem due to the high cheese whey pollutant load. Therefore, it is important to use this by-product and its components in an increasing number of applications, especially as food ingredient. This review aimed to show the technology of production of butter from whey cream, as well as showing the physico-chemical, sensory, and nutritional characteristics of the product. There were no significant variations in the physico-chemical composition of milk cream butter and whey cream butter in the literature available. As the technology to produce whey butter is quite simple, this by-product has potential to be exploited by the dairy industry. Additionally, further studies on production process, characterization, and sensory analysis are required to enable its large-scale production.

Keywords: Milk cream; Physico-chemical composition; Whey cream; Fermentation; Lactic acid bacteria; By-products.

Resumo

O soro de queijo é o principal coproduto obtido durante o processo de fabricação de queijos. Apesar de possuir um valor nutricional elevado, cerca da metade do volume de soro gerado ainda é descartada de forma incorreta, constituindo-se uma prática prejudicial para o ecossistema devido à enorme carga poluente do soro de queijo. Dessa forma, é importante a utilização desse coproduto e de seus componentes em um número maior de aplicações, especialmente como ingrediente alimentício. O objetivo deste artigo de revisão é apresentar a tecnologia para produção da manteiga a partir do reúso do creme de soro de queijo, demonstrando as características físico-químicas, sensoriais e nutricionais do produto, e apontando as alternativas e possíveis utilizações para os principais componentes do soro. Na comparação entre a manteiga de creme de leite e a manteiga de creme de soro, na literatura disponível, os resultados não

apresentam variações significativas em relação à sua composição físico-química. Dada a simplicidade da tecnologia de produção, a manteiga de soro possui potencial para ser explorada pelas indústrias lácteas. Além disso, mais estudos sobre o processo de fabricação, caracterização e análise sensorial são necessários para viabilizar sua produção em maior escala.

Palavras-chave: Creme de leite; Composição físico-química; Creme de soro; Fermentação; Bactérias ácido-lácticas; Coprodutos.

Highlights

- Butter obtained from cheese whey had a good nutritional composition
- Whey cream butter is characterized by high concentration of unsaturated fatty acids
- Shelf-life of whey cream butter is reduced due to oxidation of unsaturated fatty acids

1 Introduction

Cheese whey is the aqueous portion separated from curd during the production of cheese or casein. It comprises approximately 80 to 90% of the milk volume used in cheese making and is thus the main dairy by-product (Tsermoula et al., 2021). Its physico-chemical composition derives from several factors, including the type of cheese manufactured, composition of the milk used, as well as animal diet, lactation stage, and management (Trindade et al., 2019).

Considering there is a steady increase in annual cheese production, the volume of whey generated has also increased, which requires new strategies to enhance its use and application (Elleuch et al., 2020). The pollutant potential of cheese whey is due to its Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), and approximately half of its volume generated is processed and used in animal or human diets; the rest is either sent for effluent treatment, which generates additional costs, or resulted from inadequate sewage disposal, *i.e.*, there is water or soil contamination, thus causing environmental issues (Izzo et al., 2020; Macwan et al., 2016). Therefore, the use of cheese whey is of high interest to the industry due to the amount produced daily and to its nutritional quality, which leads to its potential as ingredient in food production (Rama et al., 2019).

One economic and feasible option for dairy products is the production of butter using cheese whey. For that purpose, whey cream is separated from the aqueous fraction of cheese whey and processed to obtain whey cream butter (Aly, 2009; Jinjarak et al., 2006; Morin et al., 2006; Nadeem et al., 2015). Therefore, this review aimed to show the technology of production of butter from whey cream, as well as showing the physico-chemical, sensory, and nutritional characteristics of the product. Firstly, there will be a discussion about cheese whey, emphasizing its composition and pollutant load. Then, different types of butter in the market will be described, along with their compositions and production processes. Finally, the technique to obtain whey cream butter will be described, comparing milk cream butter and whey cream butter through their physico-chemical parameters, obtained from several studies.

2 Cheese whey

Cheese whey can be defined as the yellow-green liquid that is separated from curd during the production of some dairy products (Enteshari & Martínez-Monteagudo, 2020). It accounts for 80 to 90% of the milk processed, containing approximately 55% of milk nutrients. It is chiefly composed of water (~90%), lactose (4-5%), soluble proteins (0.6-0.8%), lipids (0.4-0.5%), mineral salts (0.5-0.7%), and components such as

organic acids and B-complex vitamins (Enteshari & Martínez-Monteagudo, 2020; Zikmanis et al., 2020). Cheese whey has 20% of milk proteins, containing all essential amino acids, and it is a mixture of globular proteins composed of β-lactoglobulin (β-LG; ~50%), α-lactalbumin (α-LA; ~20%), immunoglobulins (IgC; <10%), and serum albumin (BSA; <6%), as well as glycomacropeptides (GMP) and other components, such as peptides, lactoferrin (LF), lactoperoxidase (LPO), and lysozyme (Coltelli et al., 2020; Maciel et al., 2020; Trindade et al., 2019).

Cheese whey might be classified as either sweet whey or acid whey according to its acidity level. Sweet whey has pH of 5.6 – 6.5 and is obtained via the enzyme coagulation of milk proteins. Acid whey, on the other hand, has a pH below 5 and is obtained by acid coagulation in the production of cheese (Ryan & Walsh, 2016; Zikmanis et al., 2020). Sweet whey is used as ingredient in the production of flour and meat products, beverages, and baby food, due to its nutritional value and sweet taste. Acid whey is used in the production of fruit beverages, fermented milk, and salad seasonings (Faucher et al., 2020; Smithers, 2015; Panghal et al., 2018).

The dairy industry has had a sharp growth, thus leading to an increase in the volume of cheese whey produced (Elleuch et al., 2020). The whey volume produced worldwide has increased over 100% and approximately over the last 45 years and it reached the amount of 160 million tons in 2020. According to the Global Cheese Market, the global production of cheese in 2023 is estimated to be 26 million tons, leading to an estimated cheese whey volume of 230 million tons (Choi et al., 2020; Rama et al., 2019).

Considering the high volume of cheese whey produced and its nutritional composition, the use of this by-product is of great interest to the dairy industry. Half of the volume of whey produced is currently used in the industry; approximately 2/3 of this volume is used as either liquid or powder whey and approximately 1/3 is used as protein concentrate and isolate, and whey hydrolysates. Figure 1 shows the main cheese whey components and some uses (Izzo et al., 2020; Mollea et al., 2013). The approximate composition (in dry base) of the whey, after extracting the fat to produce the whey butter, is 77% of lactose, 12% of proteins, and 11% of mineral salts (Zikmanis et al., 2020).

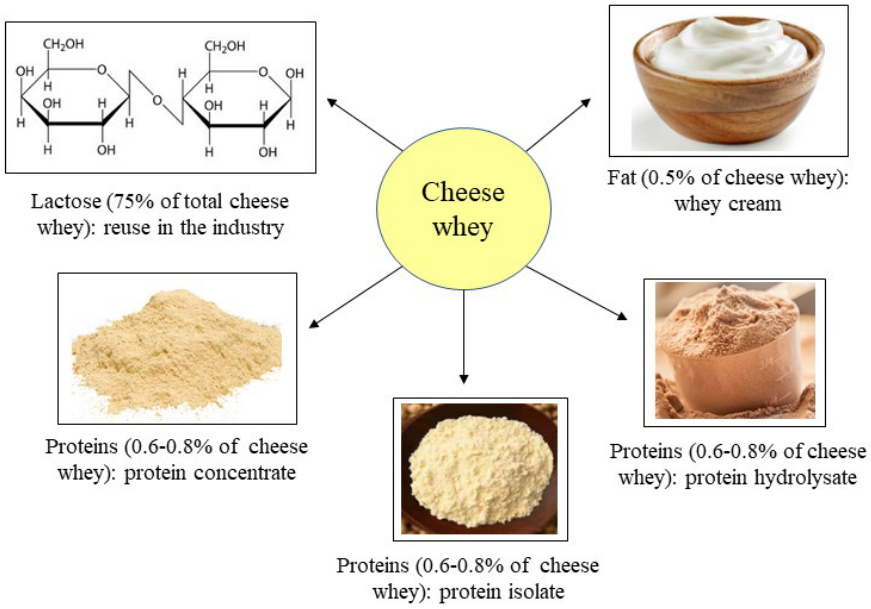

Figure 1. Main cheese whey components and uses.

Despite its characteristics, approximately 50% of the cheese whey volume generated by the dairy industry is still sent to effluent treatment stations or may be discharged onto the soil or into water bodies (Izzo et al., 2020; Macwan et al., 2016; Smithers, 2015; Panghal et al., 2018). Cheese whey is considered

a pollutant due to its BOD (30-50 g/L) and COD (60-80 g/L) (Meng et al., 2020). Lactose, which comprises approximately 75% of total solids in cheese whey, is the major component responsible for these values (Choi et al., 2020). According to Ryan & Walsh (2016), the polluting potential of whey is 100-175 times higher than the same volume of domestic wastewater. Therefore, the disposal of untreated cheese whey into the environment is responsible for an increased oxygen demand, thus leading to eutrophication and shifts in the physico-chemical characteristics of the environment into which it is discharged (Li et al., 2020; Meng et al., 2020).

3 Milk cream butter

Butter is a greasy product exclusively derived from milk. It consists of a complex mix of Short- and Medium-Chain Fatty Acids (SCFA and MCFA) (4 to 12 carbons), such as caproic, caprylic, and butiric acids (which are the most abundant). Aside from proteins, butter also has water, minerals, vitamin A, and β-carotene in its composition. It has a typical aroma derived from aromatic substances, such as diacetyl and acetaldehyde (Karaca et al., 2018; Obeidat, 2020; Tamura et al., 2021).

Butter contains a minimum milkfat content of 80% and a maximum water content of 16% (Buldo et al., 2013). However, the physico-chemical and micro-structural properties of butter might differ due to several factors, such as milkfat composition, water content, and processing and storage conditions (Buldo et al., 2013; Food and Agriculture Organization of the United Nations, 2011; Sert & Mercan, 2020). Milk cream is the major raw material in the production of butter, and it directly affects end-product quality. Thus, it is important that the cream is filtered and treated before churning, so that the end product complies with hygiene standards and develops the sensory characteristics required for consumption. Cream is the milk fraction rich in fat, comprised basically of water (60%), lipids (37%), and small concentrations of proteins, carbohydrates, and minerals (3%) (Ewe & Loo, 2016; Karaca et al., 2018).

Butter is produced by churning of milk cream (whether fermented or not), which forms a stable water/oil emulsion. During this process, a by-product called buttermilk is created, with a good nutritional quality due to its composition, which includes caseins, whey proteins, minerals, and material derived from the Milk Fat Globule Membrane (MFGM) (Qu et al., 2019; Sakkas et al., 2020).

The butter-making process starts with milk centrifugation, through which the cream is obtained; this cream is filtered to remove debris that might affect product quality. After that, fat content is standardized and pH is adjusted, where required, so that the butter has suitable fat and acidity percentages. Among the key stages are cream pasteurization and cooling, for cream microbiological control. In addition, depending on the type of butter produced, microorganisms are used for fermentation, and they are responsible for developing suitable butter sensory characteristics. After fermentation, the cream is churned to form butter and separate buttermilk, followed by rinsing and optional salting. The final stage is milling, *i.e.*, butter grains undergo aggregation until they form a homogeneous and elastic mass. Finally, the product is packaged and stored at refrigerated temperatures (Deosarkar et al., 2016; Dias et al., 2010).

Different types of milk butter are available in the market. However, the most popular are sweet cream butter and cultured cream butter (Table 1). Sweet cream butter has a sweeter taste compared to other butters due to its pH. Cultured cream butter has a more acidic pH due to the addition of Lactic Acid Bacteria (LAB) for the fermentation process. During this stage, bacteria are used as raw material factories, developing the taste, aroma, and texture that are typical of butter. These microorganisms are responsible for the development of the typical "butter aroma" of cultured cream butter, owing to the formation of the diacetyl compound. Sour cream butter is another type of butter produced via cream fermentation. However, specific strains of LAB are used here; typically, from the genus *Lactococcus*, such as *L. lactis* and *L. paracasei.* Another type of sour cream butter available in the market is whipped butter, which has a suitable spreadability owing to the addition of nitrogen gas in the cream churning stage (Budhkar, Bankar & Singhal, 2014; Jinjarak et al., 2006; Lorenzen et al., 2013).

Table 1. Physico-chemical characteristics of different types of milk cream butter.

Types of butter	Microorganisms	Physico-chemical characteristics	References
Cultured cream butter	*Lactobacillus acidophilus*	Diacetyl: 340 µg/kg	Ekinci et al. (2008)
	Bifidobacterium bifidum	Lactic acid: 73.9 mg/100 g	Lorenzen et al. (2013)
	Streptococcus thermophilus	Butiric acid: 0.83-1.18 mg/g	Schieberle et al. (1993)
	Lactobacillus bulgaricus	pH: 4.38 ± 4.81	Jinjarak et al. (2006)
	Lactobacillus helveticus	Fat: 75.19-93.03%	Ewe & Loo (2016)
		Protein: 0.89-1.31%	
		Texture[a]: 2232 N	
Sour cream butter	*Lactococcus lactis*	Diacetyl: 110-620 µg/kg	Musiy et al. (2017)
	Leuconostoc mesenteroides	Butiric acid: 2660-4480 µg/kg	Schieberle et al. (1993)
	Enterococcus italicus		Yu et al. (2018)
	Lactobacillus paracasei		Mallia et al. (2008)
Sweet cream butter	-	pH: 6.12-6.70	Peterson & Reineccius (2003)
		Diacetyl: 6.6 µg/kg	Lorenzen et al. (2013)
		Butiric acid: 192 µg/kg	Jinjarak et al. (2006)
		Fat: 96.03%	
		Protein: 0.92%	
		Texture[a]: 2752 N	
Whipped butter	-	Cream fat: 30-36%	Clark et al. (2009)

[a]Maximum force required to penetrate the samples.

According to Market Watch (2020), the global butter market had a turnover of approximately 54 billion dollars in 2020, and 2026 is estimated to reach over 60 billion dollars, with a growth rate of 3% per year. In addition to the butters shown in Table 1, other types of butter have drawn the attention of the dairy industry, e.g., whey cream butter, produced from whey cream (Jinjarak et al., 2006).

4 Whey cream butter

Cheese whey is highly pollutant and has a high nutritional value. The high volume produced of this by-product justifies an analysis of its potential applications. One option for the industry is to add value to cheese whey by reusing it in the production of butter (Nadeem et al., 2015).

As shown in Figure 2, whey cream is removed by whey centrifugation. After the separation, whey cream is treated and churned, following the conventional milk cream butter-making process (Aly, 2009; Budhkar et al., 2014; Jinjarak et al., 2006).

The physico-chemical composition of whey butter has no significant differences to milk butter (Table 2) (Aly, 2009; Jinjarak et al., 2006; Morin et al., 2006; Nadeem et al., 2015).

Table 2. Comparison of physico-chemical characteristics of whey cream butter obtained in different studies.

References	Jinjarak et al. (2006)	Morin et al. (2006)	Aly (2009)	Costa et al. (2010)	Nadeem et al. (2015)
Characteristics	Lipids: 95.80% Protein: 0.75% Solids: 87.66% Ash: 0.09% Lactose: 3.36% pH: 6.36 Texture: 1792 N	Lipids: 80.84% Protein: 0.50% Solids: 87.41% Ash: 0.08%	Lipids: 80.00-80.70% Solids: 83.85-84.55%	Lipids: 96.93% Protein: 0.55% Solids: 85.95% Ash: 0.08% Sphingomyelin 1.16%	Lipids: 83.10% Solids: 84.70% Fatty acids: 0.11%

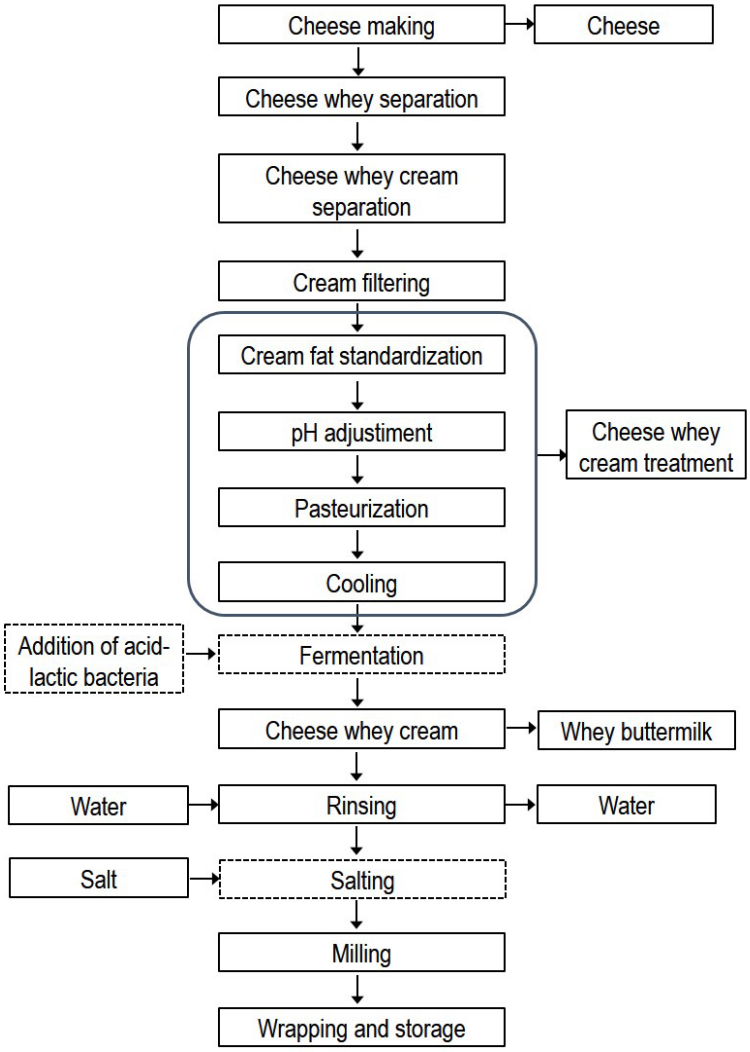

Figure 2. Flowchart of the whey cream butter-making process.

According to Table 2, lipid, solid, protein and ash contents in whey cream butter varied from 80 to 96%, 83 to 87%, 0.50 to 0.75%, and 0.08 to 0.09%, respectively. The studies published did not employ fermentation in the production of whey cream butter and compared it to sweet cream butter. The process that employs LAB resulted in reduced butter pH and in improved aroma, due to diacetyl release (Jinjarak et al., 2006).

Whey cream butter is characterized by high concentration of unsaturated fatty acids (Aly, 2009; Nadeem et al., 2015) and by biologically active compounds (such as sphingomyelin and mucins) in the MFGM. According to Aly (2009), the linolenic fatty acid content is approximately 50% higher in whey cream butter than in milk cream butter, which provides whey butter with nutritional quality and higher healthiness than milk cream butter. Furthermore, there are studies (Aly, 2009; Morin et al., 2006; Nadeem et al., 2015) indicating that the physico-chemical composition of whey butter has no significant differences compared to milk butter.

Regarding sensory characteristics, the major difference between whey butter and the others is its softer texture due to the higher concentration of unsaturated fatty acids in whey cream (Aly, 2009). According to Jinjarak et al. (2006), while the texture of milk cream butter was approximately 2752 N, the texture of whey butter was 1792 N. Shelf-life of whey butter is reduced due to oxidation of these unsaturated fatty acids.

Therefore, the use of antioxidants in the production of whey butter is an alternative to delay the autoxidation process (Chen et al, 2004; Nadeem et al., 2015; Lee, 2020).

Literature available on whey butter (Aly, 2009; Jinjarak et al., 2006; Costa et al., 2010; Morin et al., 2006; Nadeem et al., 2015) indicated that this product is an alternative to reuse one component of cheese whey in the dairy industry, thus reducing the organic load of the whey, and consequently the cost of treatment. Moreover, the butter obtained from cheese whey had a good nutritional composition, which along with the significant cheese whey volume generated, could justifies the need to produce this type of product on an industrial scale. The approximated yield was of 5 kg of butter/1000 L of whey, considering the fat content in cheese whey.

5 Conclusion

The development of technological strategies to reuse the main components of cheese whey as a by-product is justified by the increased volume generated, its pollutant load, and its nutritional quality. Therefore, the reuse of dairy-generated cheese whey at a large scale is important, in addition to exploring new and differentiated ways to use whey and its components as dietary ingredients.

Butter-making process is relatively simple, and it might be applied to fat separated from cheese whey, called whey cream. There are few studies on the characterization of butter obtained from whey cream, and the comparison of these types of butter with milk cream butter indicates a potential for developing a product with higher added value, good nutritional characteristics, and suitable sensory attributes.

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