Influence of Whey Protein on Bakery Products

Subjects: Others
Contributor: Marina Rocha Komeroski , Viviani Ruffo de Oliveira

In addition to being an important source of nutrients, pasta and bakery products are consumed globally and so there is a growing need to study them in addition to other ingredients such as whey proteins. These dairy proteins are intended to improve the quality of these foods, as they have important nutritional, technological, and sensory properties that can be exploited. The importance of new formulations in the quality features of pasta and bakery products and gaining an understanding of how the ingredients can interfere with these foods are described. A summary of the latest progress in the application of whey protein in bakery products, as well as their types and quantities from a physicochemical and sensory point of view, is presented.

baking whey products physicochemical properties

1. Introduction

Bakery products are generally made with cereals and submitted to high temperatures in order to be consumed [1]. These products are widely consumed and well-accepted all over the world. They can be found easily, are practical to be consumed, and are usually appreciated by people of different ages [2], in addition to being an important source of nutrients [3]. According to data from the Brazilian Bakery and Industry Association (ABIP) [4], consumers have become more demanding regarding the quality of the products, opting for healthier choices, with natural ingredients combined with high technology. In this sense, the development of foods enriched with proteins has great potential to help in meeting the nutritional needs of the population, given the protein deficit found in some places in the world. However, making these foods attractive is a challenging task [5].

Kittisuban, Ritthiruangdej, and Suphantharika [6] mentioned that dairy products are some of the most important ingredients in any gluten-free formulation and are widely used for functionality, nutritional value, and to make bread more easily. Whey is a dairy by-product that remains liquid from the precipitation and removal of curds during the manufacture of cheese [7], and its proteins may be interesting in bakery products, other dairy products, and infant formulas because they have favorable technological properties such as easy solubility, emulsification, and anti-allergic action [8]. Since whey proteins correspond to 20% of all milk proteins and have important nutritional and biological properties [9][10], their use in bakery products can favor physical aspects, such as emulsion and stabilization capacity, in addition to improving sensory characteristics [11]. Years ago, whey was considered a polluting effluent from the dairy industry, and its high production volume and organic content were commonly discarded without treatment in the environment. Due to legislation, technological evolution, and the promise of whey proteins, this paradigm has been changed [7].

Whey protein can be obtained in the industry via different processes, resulting in the following products, according to Sinha et al. [12]: Whey Protein Concentrate (WPC), which is the product obtained by removing the non-whey protein constituents so that the final product contains up to 80% protein; Whey Protein Isolate (WPI), which goes through a filtration process, where the lactose and milk fats are removed, which generates a higher degree of purity, with a final protein content between 80 and 95%; and Whey Protein Hydrolyzate (WPH), which is the result of the hydrolysis of whey protein molecules, manufactured from WPC or WPI, forming smaller protein segments, such as amino acids and low-molecular-weight peptides, which makes it an easier product to digest and absorb.

The interest in whey has increased considerably in recent years. Whey proteins and whey as a food ingredient have been “rediscovered” and have been increasingly frequently and successfully used in the food industry [13]. Thus, the addition of whey proteins in food products seems to be an alternative to make the consumption of these proteins more convenient and sensorially more attractive, considering their positive effect on the chemical, physical, and sensory characteristics of bakery products in general [14].

In addition, according to Paul, Kulkarni, and Chauhan [15], when whey is incorporated into bakery and pasta products, it can offer benefits, not only technological, but also sensory and nutritional, such as enhancing sensory attributes, contributing a high calcium content, aiding in the dispersion of shortening, providing structure to bakery products through the formation of heat-set irreversible gels, enhancing water binding in the dough, improving moisture retention of a finished product, which enhances consumers’ perception of freshness, improving stable foaming and whipping, replacing egg albumin, enhancing microbiological safety, lowering fat absorption in fried products, and contributing to browning and crust development.

Whey proteins have great potential both as a source of valuable nutrients and as a basis for functional foods that will contribute important health benefits to consumers [16].

2. Findings on Different Types of Breads Made with Whey Proteins (WP)

Song, Perez-Cueto, and Bredie [5] made rye bread with 4% and 7% of WPH + WPI. This bread was evaluated technologically and sensorially, and for formulations with 7%, regardless of the protein used, a more cracked texture was verified. The crumbles of this bread seemed more compact, firmer, and less porous, and the same was observed by Erben and Osella [17] when they added 20% of WPC. However, Song, Perez-Cueto, and Bredie [5] noticed an increase in softness when the protein concentration decreased to 4%, reducing the brittle texture. Gani et al. [3] observed via scanning electron microscopy that a rupture in the well-defined protein-starch complex and the shape of starch granules changed as the whey protein concentration increased in bread produced with wheat flour. These authors found increased foaming ability as WPC increased. Shabunina et al. [18] observed that 7% of WPC had a negative influence on bread dough rheology. Low water binding capacity and specific volume, as well as a hard crumb, make the usage of this product in bread baking unacceptable. The destruction of disulfide bonds leads to an increase in the fluidity of the dough and a decrease in its gas-holding capacity. The positive influence of WPC on the crust color should be stated and it can be explained by the high lactose content in this protein. Whey-based ingredients in bread can enhance crust browning, improve crisping qualities, enhance crumb structure, and has the potential to slow the staling of bread, thus increasing shelf-life and enhancing bread flavor. In sourdough bread, the distinctive flavor of acid whey can enhance the flavor, contributed to by the fermentation [15]. According to Song, Perez-Cueto, and Bredie [5], the foaming property of whey protein could generate greater fragility and, according to Gani et al. [3], the high-water binding capacity may be the reason for the increase in the noticed dryness during chewing, which was also observed by Pico et al. [19] using 10% of WPI, with a statistically significant difference for the treatment without whey protein (WP). These authors were unable to evaluate the use of 5% of WP since the bread could not be removed from the tray. Srikanlaya et al. [10], evaluating elasticity, cohesiveness, and chewability in gluten-free rice bread associated with 2, 4, and 6% of WPC and wheat bread, observed that these texture parameters were not influenced by the amount of WPC added. Cohesiveness was also lower in the study of Erben and Osella [17] with the same protein, but in contrast, elasticity showed no significant effects and chewability was higher when compared to the control (100% wheat flour).

Gani et al. [3] observed that water absorption decreased significantly ($p \leq 0.05$) with the addition of 5, 10, and 15% of WPC, as well as decreased dough extensibility and peak viscosity. The addition of WPC improved bread porosity, water absorption, development time [10], and dough stability [3][17].

The volume of bread is extremely important for consumers because they want bread that appears to be soft and not so dense [3]. In the study by Srikanlaya et al. [10], using the same amount of WPC (2, 4, and 6%) and soy protein isolate, the authors observed that the specific volume was higher in bread made with whey protein (WP), unlike the findings of Erben and Osella [17] and Pico et al. [19] who found bread with lower specific volume with the use of 10% of WPC and WPI, without a statistical difference in pea protein.

Sahagún and Gómez [20] used 30% of animal and vegetable proteins in the elaboration of gluten-free breads associated with corn starch. As a result, bread made with 30% WPI showed a lower specific volume, which was explained by the low water retention capacity, influencing the rheology of the dough, lower weight loss since they had less exchange surface, and greater hardness due to the strengthening of the elastic structure of the dough.

Gluten-free dough is a complex semi-liquid system characterized by high density and low elasticity that contains polysaccharides and other structure-forming components, viscosity-increasing and dough-stabilizing substances, and more water than conventional wheat dough. When baking, the proteins are denatured with increasing temperature, and starch gelatinization occurs. A sufficiently strong and flexible spatial structure should be created to maintain the expanding gas bubbles and not collapse during the baking or cooling of the product. However, gluten-free flour and starches do not create this structure. In this sense, proteins affect the rheological properties and the water binding in the dough, interacting with starch and lipids, and can contribute to the stability of the dough and the structure of the final product [21].

Generally, gluten-free mixtures are primarily composed of carbohydrates and lack protein content. This can affect the bread structure and quality since gluten, which is responsible for obtaining raised bread loaves, is missing; its structure deteriorates from that of conventional bread. In wheat bread, the open cellular structure is due to the elasticity of the gluten that, after mixing with water, is able to entrap carbon dioxide produced by yeasts during fermentation in the leavened dough, causing the dough to rise [22].

It is difficult to mimic the properties of gluten with other proteins. However, proteins of animal origin have good solubility, high emulsifying and foaming capacity, and high stability [22]. The microstructure of whey protein is different from other dairy proteins in that it does not have thermal stability above 70 °C. Therefore, it completely denatures above such a temperature, leading to the formation of a good protein network [23].

Regarding the texture changes caused by protein enrichment, the increase in hardness and elasticity could be explained by heat-induced aggregation [4]. The highest firmness in terms of peak strength was found with the addition of 15% of WPC in the study by Gani et al. [3]. Pico et al. [19] found modifications in crust thickness and increased moisture content of gluten-free bread from rice flour and corn starch with the use of 10% WPI. Changes in crust thickness were also observed by Erben and Osella [17], who evaluated the effect of replacing wheat flour with 5, 10, 15, and 20% of WPC. These results can be explained by changes in the matrix composition, which generate different structures in the dough [17].

Among animal proteins, whey protein was the one that made bread darker due to the Maillard reactions that occur between amino acids and reducing sugars [3][16][24][25]. This divergence in the origin of proteins occurs due to the difference in the degree of solubility of the proteins, in addition to the lower levels of essential amino acids in proteins of plant origin [26]. Kristensen et al. [27] point out that different plant sources matter when comparing the protein issue since the amino acid composition is not identical. Soy, for example, unlike other vegetable protein sources, contains all essential amino acids, although in small amounts when compared with animal proteins. These authors also point out that it is difficult to obtain a large amount of protein from plant sources without compromising palatability. Madenci and Bilgicli [28] noted that resistance to dough extension was positively affected by 8% of WPC, but negatively for elasticity. In relation to color, this bread became less yellowish and less luminous. Gonçalves et al. [29] analyzed the influence of WPI in bread with and without yeast. The authors concluded that the antioxidant potential of WPI was eliminated by the fermentation process. In unleavened bread, it was demonstrated that the WPI maintained its biofunctionality with the use of up to 10%, but presented higher texture parameters, such as hardness, chewability, and gumminess. Erben and Osella [17] observed the same with respect to texture parameters, with the use of up to 20% of WPC. A decrease in the quality of wheat bread with the addition of 15% of WPC, pea flour, and soybean degrease was observed by Erben and Osella [17]. Each of the ingredients used provides a loss of gas retention properties and the characteristic taste of bread. According to Fennema, Damodaran, and Parkin [30] and Araújo et al. [31], the presence of gluten, through proteins called gliadins and glutenins, results in a viscoelastic network, adherent and insoluble in water, capable of trapping the air during fermentation. For Madenci and Bilgicli [28], Syrian bread with 4 and 8% of WPC obtained a higher ash and protein content than the control, with wheat flour. This finding corroborates the study by Erben and Osella [17], who also observed a higher fiber content. Since lysine is a limiting amino acid in cereal products, these authors consider the use of WPC associated with other food sources sufficient to meet the recommended needs.

Bread made with chickpea and cassava flour associated with 20 and 30% of WPI + WPH showed promising levels of protein, lipids, total amino acids, and fibers [32]. The loaves with whey protein added showed lower luminosity but technological quality similar to wheat bread. Ferreyra et al. [33] considered their results promising as well since they could turn a traditional type of bread into an important source of proteins. The formulations developed in the aforementioned study could be successfully used for innovation in bakeries, since industry and the population are aware of nutritionally enhanced products to satisfy the demand of consumers interested in healthy foods, especially those applying processes, such as fermentation.

Sensory quality is a complex evaluation and is related to the perception of attributes: Appearance, taste, aroma, and texture [34]. Acceptability was assessed on a five-point hedonic scale, and the use of 15 and 20% of WPC resulted in lower grades for taste, color, and texture, which may be associated with decreased bread volume and increased crumb firmness [17]. However, for the other protein percentages (5 and 10%), more than 90% of assessors agreed according to the hedonic scale between "Liked" and "Liked a lot", while few assessors qualified the sample as "Did not like". This also occurred for the attributes of appearance, taste, and odor in the study of Madenci and Bilgicli [28], with Syrian bread with 4% of WPC added. In the sensory analysis performed by celiac and non-celiac assessors, all evaluated formulations showed satisfactory results. In the celiac group, there was no statistical difference among the treatments for any attribute. This less demanding result possibly occurred due to the difficulty in finding sensorially satisfactory products targeted for such a population [32].

Gani et al. [3] observed that in a sensory analysis performed with a 9-point hedonic scale, breads with 15% of WPC scored low (average of 4.7) for color and texture. The samples with 5% of the same proteins were considered satisfactory by the assessors in the sensory panel.

3. Characteristics of Cookies, Biscuits, and Crackers Made with Whey Proteins (WP)

Sarabhai et al. [35] evaluated 5 and 7.5% of WPC and reported an improvement in the texture characteristics of cookies with rice flour, skim milk powder, sugar, and bicarbonate. These authors observed that as the amount of WPC increased (up to 10%), the breaking resistance of cookies also increased, possibly due to the interaction between protein and starch by hydrogen binding. The same was observed by Tang and Liu [36] who also worked with cookies and values of 10 to 30% of WPC instead of wheat flour.

Crackers were made by Nammakuna, Barringer, and Ratanatriwong [37] with rice flour, hydrocolloids, and different percentages of whey protein isolate. The use of 10% of WPI improved dough elasticity. According to the authors, this was likely due to the polymeric structure of the protein, which provided water retention capacity and water distribution in the dough when compared to the control. Furthermore, the crackers containing 10% of WPI obtained the best texture and rheological properties, similar to the wheat cracker.

In the study by Tay et al. [38], the authors observed that the incorporation of WPI in crackers made with wheat decreased the thickness of the product, thus generating a thinner product. The authors noted the need for less force to break the cracker as well. The decrease in hardness in these crackers made with the addition of WPI may be due to the rupturing of the gluten network. It is possible that the addition of WPI delayed the formation of the gluten matrix by restricting the water available for gluten formation and therefore decreasing the strength of the dough matrix.

Zhu et al. [39] evaluated the addition of WPC at 8–12% to sorghum and corn flour in cookies. This addition resulted in an increase in optimal water absorption, which helped the binding of more moisture, thus softening the dough system. Cookies with 10% WPC added showed the highest hardness and flexibility both in sorghum and corn and had a significant effect on color development due to the Maillard reaction and likely caramelization, which made the cookies darker than the control.

Gluten-free cookies containing 10% of WPC had large, deep pores, a characteristic that is not ideal for this bakery product [35]. When analyzing the influence of WPC on the microstructure of the dough, Tang and Liu [36] observed that the dough had a relatively smooth surface, with starch granules incorporated into the gluten matrix, which was interrupted by hollows or ditches. In comparison with soy protein, the gluten matrix seemed more compact due to the aggregation capacity of this protein, as well as its higher water binding capacity, leading to greater stability and elasticity of the dough [8]; it was reported that a protein matrix was formed by the interaction and consequent denaturation of proteins, with the use of 40% of whey protein concentrate. The objective of the study by Sahagun and Gómez [40] was to analyze the effect of replacing flour with different types of proteins (pea, potato, egg white, and whey) in gluten-free cookies. There was an increase in the thickness of cookies with 30% of whey protein concentrate, different from that found by Wani et al. [41] who reported a decrease in the diameter, thickness, and weight parameters of the samples with the increase in the percentage of whey protein.

The replacement of wheat flour by 0–30% of WPC decreased water absorption by 11%. As the level of whey protein substitution increased from 0 to 20%, the development time of the dough also increased, and the stability time decreased due to the interference of whey protein with the gluten network [36]. Marques et al. [8] observed that the water activity of cookies with whey protein was superior to the control, without protein.

Gallagher et al. [42] observed that crackers with the highest level of whey protein addition had the lowest water activity. During baking, the water binding capacity of whey protein increased, leading to less free water availability in crackers [43]. Upon increasing WPI, there was more WPI to bind to water, resulting in a decrease in moisture content and water activity, which are always key components that influence the durability of crackers [44]. It should be noted that low water activity and moisture content are advantageous in crackers since they lead to a cracker with a longer shelf life by minimizing microorganisms.

With the increasing protein content with WPC, the viscosity of the dough also increased, while with the same amount of soy protein, the viscosity decreased. This possibly occurred because the hydration of whey proteins resulted in higher surface adhesion, which played a predominant role in increasing the dough viscosity. However, in the case of soy protein hydration, there was a greater dilution of gluten, leading to a decrease in viscosity [36].

Tang and Liu [36] also realized that the texture was affected in their study, in which the hardness of cookies increased as the amount of WPC also increased, in comparison with soy protein. This was likely due to the superiority of the gelling property of whey protein, which, when heated, leads to a higher dough hardness. The texture characteristics of cookies with 2 and 4% whey protein concentrate did not show significant differences from the control with wheat flour [41].

Regarding colorimetry, the values of a*, which vary in a spectrum of colors from green to red, suggested cookies were more reddish with the incorporation of whey proteins from concentrated milk and a significant decrease in brightness, which was primarily attributed to the reactions of Maillard [8][36][37]. In this chemical reaction, there is the condensation of reducing sugars with amino acids when submitted to a heat treatment, forming compounds that result in a dark color and a peculiar aroma [45].

There was no statistical significance for weight, yield, diameter, thickness, specific volume, and expansion factor with the addition of up to 54.1% of WPC and up to 33.4% of margarine in cookies [8]. Regarding the proximate composition, treatment with 40% protein achieved the highest amount of protein, moisture, ash, and fat, but the lowest carbohydrate and energy content. It is worth mentioning that WPs have also been considered a promising fat substitute due to their high nutritional value and biological and functional qualities, even mimicking certain properties of lipids and with a similar performance of fats in foods [46].

Wani et al. [41] realized that cookies with 6% of WPC added showed higher protein, moisture, fat, and ash content compared to the control, without addition. In the study by Fernandéz et al. [47], regarding the proximate composition, the protein content was higher for cookies with 7.5% whey protein isolate. The fact that cookies with 7.5% of WPC achieved higher results for the lipid macronutrient can be attributed to the method used to obtain this protein (nano/ultrafiltration).

In the sensory analysis of cookies with 30% of WPC, they were classified as very good for appearance but not well classified for taste [45]. This addition resulted in a decrease in the score of all sensory attributes, primarily color and texture [36]. The same was observed by Marques et al. [8] in relation to this last-mentioned attribute, except for the addition of 40% of WPC, which did not obtain a difference for the control without protein. It is worth mentioning that this treatment also had the highest amount of margarine, which may have contributed to the grades given by the assessors, since they expect crunchy and, at the same time, soft products. All the treatments analyzed (25.9, 40, and 54.1%) obtained acceptance levels above 70%. In Tang and Liu [36], the amount accepted by the assessors was 10% of WPC, with a grade of 6.2 against 6.9 for the control without protein.

Considering that cookies are highly consumed and well accepted, Fernandéz et al. [47] evaluated preparations enriched with three concentrations (2.5, 5, and 7.5%) of different types of WP: Concentrate and isolate. In the sensory evaluation, on a hedonic scale of 10 points, with 0–5 points being “I don’t like much” and 6–10 points being “I like much”, there was only a statistical difference for the flavor attribute, and cookies with 7.5% of WPC obtained the highest average (9.04).

Wani et al. [41] observed that cookies with 4% of WPC were more acceptable, as well as cookies with 30% of the same protein [40]. Marques et al. [8] concluded that WPC is an excellent ingredient for bakery products, improving aroma, flavor, texture, and shelf life, in addition to the nutritional value of these products.

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