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Research Article

Improving chemical, rheological and sensory properties of commercial low-fat cream by concentrate addition of whey proteins

Ali R. Mulakhudair
Department of Food Health and Nutrition, College of Food Sciences, Al-Qasim Green University, Iraq
Dhia I. J. Al-Bedrani
Department of Dairy Science and Technology, College of Food Science, AL-Qasim Green University, Babylon, Iraq
Jasim M. S. Al-Saadi
Department of Dairy Science and Technology, College of Food Science, AL-Qasim Green University, Babylon, Iraq
Dhia Hattif Kadhim
Department of Dairy Science and Technology, College of Food Science, AL-Qasim Green University, Babylon, Iraq
Ali M. Saadi*
Department of Animal Production, Technical Agricultural College, Northern Technical University, Mosul, Iraq

*Corresponding author. Email: ali.mohammed@ntu.edu.iq

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Abstract
The present study was conducted to determine the effect of whey protein concentrate (WPC) addition on the commercial low-fat cream's chemical, rheological and sensory properties. WPC was added to the low-fat cream (10% fat) in ratios of 1.0, 2.5, and 5.0% to represent the treatments C1, C2, and C3, respectively.In addition, a fat-rich, positive control treatment (C +) with a fat percentage of 30% and a negative low-fat control treatment (C-) with a fat percentage of 10% were investigated without adding WPC. Chemical tests were carried out, including the percentage of moisture, protein, fat, carbohydrates, total acidity, and pH, as well as rheological tests that included; hardness, springiness, and Cohesiveness. Also, a sensory evaluation was conducted. The results showed a decrease in the moisture percentage of the added treatments with the increment of the added WPC quantity. Also, a decrease in the fat percentage and pH of the WPC addition treatments was observed, combined with an increment in the percentage of protein, carbohydrates, ash, and total acidity. Regarding the microbiological properties, no bacterial or mycological contamination was observed during the manufacturing and storage periods. The results also showed the improvement of rheological and sensory characteristics by increasing the percentage of WPC addition compared with the positive and negative control treatments. The present study would be helpful in the production of low-fat cream fortified with whey proteins with high nutritional value.

Keywords: Low-fat commercial cream, Rheological properties, Sensory evaluation, Whey proteins concentrate

INTRODUCTION

Many studies are interested in manufacturing dairy products in which foodstuffs are added, whether these materials are derived from milk or plant materials. Some of them are added to the manufacture of ice creams, such as dried fruits or natural sweeteners (Hasan *et al.*, 2020; Saadi *et al.*, 2022). Some of it is added in the manufacture of yogurt, such as adding dried mushroom powder, stabilizers, or different types of milk (ALKaisy *et al.*, 2023; Saadi *et al.*, 2022; Al-Bedrani *et al.*, 2023). Some of it is added in the cheese industry, such as using vegetable oils, adding cardamom, adding the enzyme trypsin in the manufacture of cheese from buffalo milk, or using a mixture of sheep and camel milk (Saadi *et al.*, 2019; Saadi, 2018; Salih *et al.*, 2021; Ali and Saady, 2019).

The cream is a fat-rich milk product obtained from fresh milk with a physical separation process (Lee *et al.*, 2018). The special texture of the cream results from the even distribution of fatty globules in the water-hydrophilic phase, which is highly dependent on the fat content (Singh and Saha, 2023). The diameter of these fat globules at skim milk processing is 1-8 microns (Halder *et al.*, 2022). During the subsequent manufacturing processes of different cream products, the fat emulsion is mutated by the typical water until it becomes another physical state (Gaur *et al.*, 2022). Homogenization can achieve this modification, which reduces the average size of fat globules and improves the cream texture. On the other hand, the mechanical treatment of cream will lead to an unstable product (in the sense of fusion of fat globules) (Xiao, 2020). Mechanical treatment and simultaneous whipping are essential for turning the cream into a stable foam (Han *et al.*, 2023). The fat content of cream commonly ranges from about 10 to 50%; however, low-fat products that are not meeting this standard are coffee cream (≥10% fat in Germany), half-half cream (≥ 10.5% fat in the United States), and half fat (≥ 12% fat, in the UK) and light cream (≥ 12% fat, in France) (Shazly *et al.*, 2022). Fat consumption and an increased risk of many chronic diseases, including coronary heart disease, atherosclerosis, high blood pressure, and tissue injury associated with fat oxidation, are strongly correlated. They are also a cause of obesity which is becoming an increasing risk not only in Western countries but most of the world (Parameswaran *et al.*,2021). Therefore, there is an increasing shift to low-calorie diets (low-fat content), which will positively affect consumer health (Watanabe *et al.*, 2020).

This has increased consumer health awareness of non-fat or low-fat dairy products. Due to the high consumption of dairy products, they have been considered to become one of the common options for reducing the fat content, so there has been a significant increase in demand for low-fat products such as yogurt, cream, and other dairy products(saadi *et al.*, 2022). Boldea *et al.*, (2021) reported that more than 70% of the fatty acids in milk fat are saturated fatty acids such as lauric, myristic, and palmitic, which are particularly the cause of atherosclerosis. On the other hand, fat plays a major role in dairy products' flavor, texture, and Cohesiveness (Waldron *et al.*, 2020). Removing fat from dairy products will negatively affect their texture and body. So, recent studies have tended to add some materials to replace the fat, improving the rheological properties of products (Saadi, 2018). These replacements have similar physical properties of fat; when added, they give a smooth texture, creamy taste, and viscosity that suits the variety of products. However, these fat replacements have a different chemical composition with different sources, either of a carbohydrate source such as inulin, β-glucan, and micro-crystallization cellulose or from a fatty source like olestra or a protein source such as whey proteins concentrates and isolates or sodium caseins (Mensink *et al.*, 2015). Kumar *et al.* (2018) mentioned that whey proteins are good fat-replacement materials because of their functional, technological, and nutritional properties due to their high biologically active protein content. Their functional properties are associated with their chemical composition and denaturation degree (Anema, 2020). Whey protein concentrate (WPC) is generally cheap; therefore, it is the ideal substitute for dried skim milk and caseins. Also, WPC gives functional properties that differ from the whole milk protein found in dried skim milk, such as solubility, emulsification, gelatinization, foam formation, reduction of whey separation, increased viscosity and increased hardness (Minj and Anand, 2020). Milk proteins, especially caseins, are natural emulsifying compounds in homogenized dairy products and creams. Casein has high emulsification properties, while whey proteins have high stability as emulsifying agents (Euston and Goff, 2019). The present study explores the possibility of partially replacing commercial cream fat with the addition of different ratios of WPC and the effect of this addition on the quality characteristics of the manufactured cream.

MATERIALS AND METHODS

Materials

The fresh whole bovine milk was used to get the cream. WPC, supplied by the Iranian company Golshad, was used. Carboxymethylcellulose was used as produced by Sigma (U.S.A.). Sucrose was used from the local markets of Hilla City.

Methods

Cream manufacturing

The raw cream was prepared by skimming 250 kg of fresh whole milk using a separator type west facia. Milk was pasteurized at 63 °c for 30 min and then cooled to 32-40 °c. After that, the fat percentage in the cream was adjusted to 30% by adding calculated amounts of fresh skim milk and adding 0.5% CMC stabilizers. Sucrose was 1% to compensate for lactose sugar. Then the mixture was heat-treated at 85 °c for 30 min and then cooled to 55-60 °c . Afterwards, antioxidants (butylated hydroxytoluene) were added at a concentration of 0.01% in the form of an alcoholic solution at 2% v/g. Then, it was homogenized and divided into five treatments positive control treatment C+(30% fat) and negative control treatment C- (10%fat) without any WPC addition and treatments C1, C2, and C3 with WPC addition in ratios of 1.0, 2.5 and 5.0% respectively. The cream was filled in plastic bottles and refrigerated at 6 °c until tests were carried out.

Chemical tests

Total acidity was determined according to AOAC (2016). pH was determined by using a pH-meter device. Fat percentage was determined by the Gerber method, according to Ling (2008), and the protein percentage was determined by the Kjeldahl method, according to AOAC (2016).

Texture analysis

Texture analyses were performed according to the method described by Bonczar *et al.* (2002) using a Brookfield CT3 Texture Analyzer. The hardness, Cohesiveness, and springiness were measured using a plastic cylinder with a 2 cm diameter that was 5 g force over the product to penetrate to a depth of 2 cm. at 1 mm / s speed).

Sensory evaluation

Sensory tests of the cream samples were conducted by several panelists experienced in the field of dairy from the Department of Food Science / College of Agriculture and Forestry / University of Mosul, and the scores were awarded according to the sensory evaluation of Flavor(45), Body and texture(30), Color and appearance (15), Spreadability(10)] forms created by Clark and Costello (2009).

RESULTS AND DISCUSSION

Chemical composition

Table 1 shows the chemical composition of the different cream treatments. The moisture percentage of the positive control treatment rich in fat C + (positive control) was 60.80%, while the C- (negative contro)l treatment of low-fat C- was 73.0%, and for the low-fat additions, treatments were 73.19, 73.38 and 74.30% of C1, C2, and C3 treatments respectively. It was noted that this percentage was high for all low-fat treatments due to the decrease in total solids by reducing fat compared to the C+ treatment. It was also noted that the moisture content of the WPC addiction treatments is higher than the negative control treatment and is directly proportional to the increase in the amount of WPC added. Overall, these findings agree with findings reported by Pluta-Kubica *et al.*, 2020 who pointed out that whey can be used in processed cheese to improve water bonding.

The protein percentage of C + treatment was 0.89%, and C- treatment was 1.34%. While for WPC addition treatments were 1.90, 2.20 and 3.80%, respectively. These results agreed with Pires *et al.* (2022), who pointed out that the substances of protein origin work to increase the percentage of the total solids and thus increase the protein percentage where there is a direct relationship between the amount of added WPC and the protein percentage of the resulting cream. Roy *et al.* (2021) also noted that fortifying the ice cream mixture with WPC increased its protein content. The fat percentage for C + treatment was 29.5%, and for C- treatment was 9.43%, while for WPC addition treatments were 40, 9.30, and 8.18%, respectively. It was observed that the percentage of fat in WPC addition treatments decreased by increasing the percentage of WPC, and this agrees with Carrillo-Lopez *et al.* (2020), who indicated that the fat percentage of processed cheese was decreased by increasing the percentage of addition of non-fatty solids. The carbohydrates percentage of C + treatment was 8.01%, and of C- treatment was 14.96%, while of the WPC addiction treatments, 13.93, 13.60, and 12.20%, respectively. The ash percentage of C + treatment was 1.52%, and of C – treatment was 1.54%, while of WPC addition treatments 1.58, 1.52, and 1.52%, respectively.

Total acidity

The cause of differences in acidity values among treatments is the differences in chemical composition and protein content. Generally, natural titratable acidity in milk and milk products relies on casein, phosphates, albumin, carbon dioxide, and citrates (Gandhi *et al.*, 2020). The results in Table 1 show the percentage of total acidity, and it reached 0.19% in C + treatment and 0.18% in C- treatment was 0.18% while the WPC addition treatments were 0.19, 0.19, and 0.20%, respectively. The results indicated that the total acidity of the WPC added treatments increased with the increase in

Table 1. Chemical composition, pH, and total acidity percentage of different low-fat cream treatments

Treatment	% Components						pH
	Moisture	Protein	Fat	Carbo-hydrate	Ash	Total acidity	
C +(30% fat)	60.80	0.89	29.5	8.01	1.52	0.19	6.5
C- (10% fat)	73.0	1.34	9.43	14.69	1.54	0.18	6.5
C1(10%fat with 1.0%WPC)	73.19	1.90	9.40	13.93	1.58	0.19	6.5
C2(10%fat with 2.5%WPC)	73.38	2.20	9.30	13.60	1.52	0.19	6.3
C3(10%fat with5.0% WPC)	74.30	3.80	8.18	12.20	1.52	0.20	6.2

the percentage of whey proteins due to the increase in the total solids in the mixture, especially the whey proteins, which are acidic reaction; in addition to that, increasing the protein concentration leads to an increase in total acidity and/or an increase in components with buffering capacity (McCarthy and Singh, 2009). The total acidity of the ice cream mixture increased by increasing the percentage of WPC (Afzaal *et al.*, 2020; Moschopoulou *et al.*, 2021).

pH

The pH results in Table 1 show that the pH of the C + treatment was 6.5, the C-treatment was 6.5, and the WPC addicted treatments were 6.5, 6.3, and 6.2, respectively. The pH values of the WPC addition treatments were decreased by increasing the amount of WPC These results agree with Al-Bedrani *et al.* (2019) and Toro *et al.* (2016), who reported that the pH of processed cheese enriched with WPC decreased compared to the control treatment. Also, the present results agree with El-Zeini Hoda *et al.* (2016), who found a significant increment in the pH value of ice cream mixes with increasing concentrations of WPC.

Rheological characteristics

The stability of fat emulsions in water depends on the membrane composition surrounding the fatty globules. The emulsion can be stabilized and/or improved its rheological properties by several methods, such as adding milk proteins and/or adding hydrocolloids or emulsifying agents(Narvhus *et al.*,2019).

Hardness: Fig. 1 illustrates the hardness values of different cream treatments and shows the improving effect of adding WPC in raising and improving the cream hardness and directly proportional to the increase in the additive WPC ratio compared to C-treatment. The low hardness of the negative control treatment may be due to the low percentage of total solids, where the fat is not being bound with the water. Adding the whey proteins would increase the hardness of the cream, and a high percentage of added WPC, positive control, can achieve a high hardness.

Cohesiveness

Cohesiveness is the strength of internal bonds making up the product body; it is the ratio of the positive area through the second compression to that of the first peak through the first compression. Fig. 2 shows the results of the cohesiveness properties tests for different cream treatments that show the obvious differences in this high Cohesiveness of both control treatments C+ and C - compared to the WPC addiction treatments. The cohesiveness C + treatment was 0.91, and of C- treatment was 0.88, while of WPC addition treatments were 0.76, 0.83, and 0.80, respectively.

Springiness

Springiness represents elasticity, which is the rate at which a deformed substance returns to its original shape when the removal of applied deforming force is The results in Fig. 3 show the springiness of the various cream treatments and it is clear that the springiness of fat-rich products depends on their fat content, with that being said, the springiness of positive and negative control treatments were increased. It was also noted from the results increasing springiness of WPC-added treatments and directly proportional to the increase in the percentage added; this was because of a weakness in the protein network due to the increase in the percentage of protein arising from the addition of WPC. This would cause an increase in springiness to the extent that it preceded the effect of fat, as is observed in the springiness of treatment C3, 5.0% of WPC was added. These results agreed with the findings of El-Zeini Hoda *et al.* (2016), who indicated that the springiness of ice cream treatments increased proportionally (p<0.001) with increasing WPC percentage compared to the control treatment.

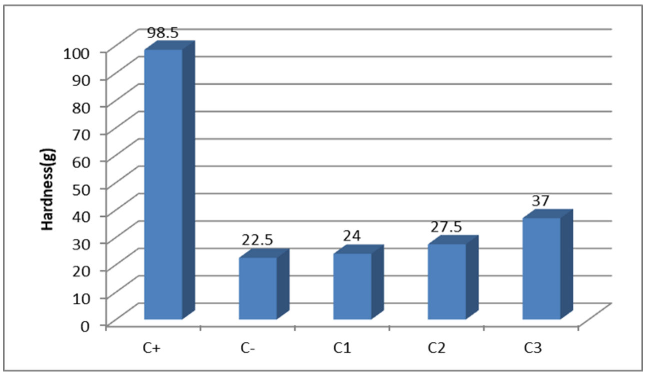

Fig. 1. *Hardness values of different low-fat commercial cream treatments (C+:control treatment with 30% fat, C-:treatment 10%fat without any WPC addition,C1: treatment 10%fat with 1.0% WPC,C2: treatment 10%fat with 2.5% WPC, C3: treatment 10%fat with 5.0% WPC*

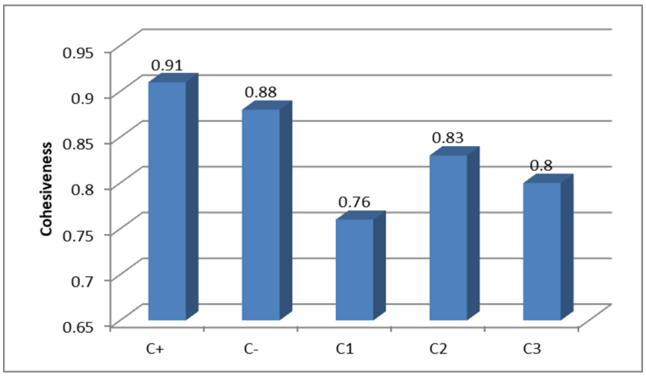

Fig. 2. *Cohesiveness values of different low-fat commercial cream treatments (*C+:control treatment with 30% fat, C-:treatment 10%fat without any WPC addition,C1: treatment 10%fat with 1.0% WPC,C2: treatment 10%fat with 2.5% WPC, C3: treatment 10%fat with 5.0% WPC*)*

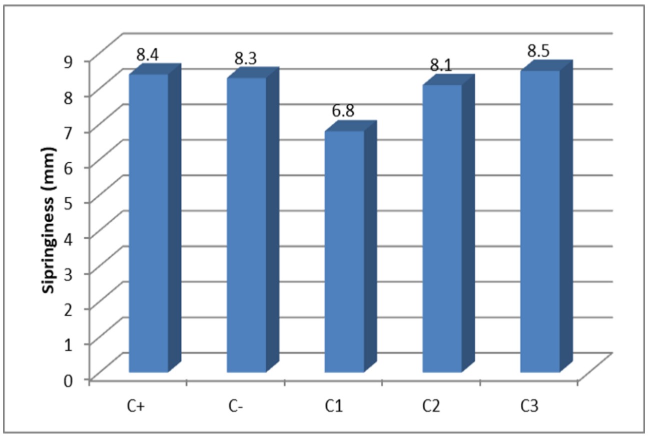

Fig. 3. *Springiness values of different low-fat commercial cream treatments (*C+:control treatment with 30% fat, C-:treatment 10%fat without any WPC addition,C1: treatment 10%fat with 1.0% WPC,C2: treatment 10%fat with 2.5% WPC, C3: treatment 10%fat with 5.0% WPC*)*

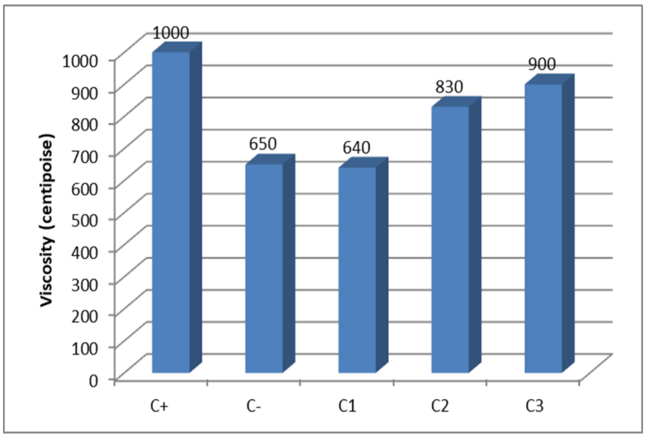

Fig. 4. *Apparent viscosity of different low-fat commercial cream treatments (*C+:control treatment with 30% fat, C-:treatment 10%fat without any WPC addition,C1: treatment 10%fat with 1.0% WPC,C2: treatment 10%fat with 2.5% WPC, C3: treatment 10%fat with 5.0% WPC*)*

Viscosity

Viscosity is the internal resistance of a material to flow when subjected to shear stress. The complex hydrodynamic properties (i.e., shape, hydration potential, and size) influence the viscosity behavior, which is independent of the time and shear rate (El-Zeini Hoda *et al.*, 2016) contradictory since no information about the flow behavior (dependence on shear rate) is given by such measurements, especially if there is an actual cross between the flow curves (strain vs. shear stress) under consideration. As the total solids concentration increased, there may be a linear or non-linear fashion of increment in the viscosity of a fluid with a transition from Newtonian to non-newtonian behavior (El-Zeini Hoda *et al.*,2016). Fig. 4 shows the cream treatments' viscosity values. The viscosity of C + and C- treatments were 1000 and 650 centipoises, respectively, while of WPC addition treatments 640, 680, and 900 centipoises, respectively. It was noted from the results of the presence of a clear effect of the WPC addition in improving viscosity characteristics and directly proportional to the increase in the percentage added, and this is consistent with Gokhale *et al.* (2018), who indicated that adding WPC to low-fat food products significantly improves their body and texture, and this improves viscosity. Also, Abbas *et al.* (2022) stated that using WPC in the production of fat-free dairy sweeteners has increased the product's viscosity and significantly improved its sensory properties due to WPC's ability to bind water. The viscosity of the C+ treatment was higher compared to other treatments, and this was consistent with Garcia *et al.* (2023), who reported that the high viscosity of the cream control treatment compared to the cream treatments supported either skim milk or low melting butterfat.

Sensory evaluation

The sensory evaluation results are shown in Table 2, which indicates that the C + treatment obtained the highest scores for all studied characteristics compared to other treatments. It was also observed that the increase in the scores given to WPC addition treatments to the scores given to C- treatment and in direct proportion to the increase in the percentage of added WPC. This is in line with what El-Metwally *et al.* (2023) found that adding WPC to milk or curd improved the sensory evaluation of ras cheese.

The results of the flavor evaluation showed that the WPC addition cream treatments had good evaluation scores and steadily increased with increasing the added amount of WPC compared to the evaluation scores given to C- treatment. These results were in agreement with Ye *et al.*, (2021) indicated that it is possible to improve the taste and flavor of foods by adding whey proteins. Texture, on the other hand, as it is a multi-parameter characteristic derived from the food structure, is difficult to be evaluated by a machine that only can measure in terms of a few specific characteristics, which can quantify the textural parameters; thus, it must be detected by several senses to perceive and describe all the attributes of a product's texture, so the texture is well evaluated by individuals (Ruiz-Capillas *et al.*, 2021).

Results of the body and texture evaluation indicated that the addition of WPC improved cream properties by giving it a better texture and higher spreadability than the C-cream treatment; this agrees with the finding of El-Metwally *et al.* (2023), who found that increasing the added amount of WPC increased the softness of cream cheese. Al-Bedrani *et al.* (2019) also indicated that adding WPC improves processed cheese's body and texture properties.

Table 2. Sensory evaluation (point(of different low-fat commercial cream treatments

Treatment	Flavor (45 point)	Body and texture (30 point)	Color and appearance (15 point)	Spreadability (10 point)
C + %30)fat)	43.0	25.6	15.0	10
C- (10% fat)	41.0	25.0	13.2	9.4
C1(10%fat with 1.0%WPC)	40.6	27.0	12.6	9.4
C2(10%fat with 2.5%WPC)	42.4	30.0	12.8	9.6
C3(10%fat with5.0%WPC)	42.0	30.0	13.6	9.6

The cream color and appearance evaluation results also show a significant improvement in the color of WPC added treatments and gradually with the increase in the added percentage compared to the color of the C - treatment. Whey proteins are one of the natural components of milk that cause color improvement. Also, whey proteins contain riboflavin, which is responsible for the yellow-green color and is one of the compounds contributing to the color. This was also observed by Minj and Anand (2022), who indicated that whey proteins contribute to the natural color of milk.

Conclusion

Low-fat cream products are widely used worldwide. Enhancing its chemical, microbiological, rheological, and sensory properties was explored in the current study by adding an increasing concentration of whey proteins, .0, 2.5, and 5.0%. The present study concluded the addition of whey proteins to low-fat ice cream led to an improvement in chemical properties and the acidity of the product was more desirable and an improvement in the rheological qualities (Hardness, Cohesivenes, Springiness, and Viscosity) as well as an improvement in the Sensory evaluation of the final product, and the best result was achieved with the highest whey protein concentration. The ramification of this study is high, and it offers low-fat cream products with better properties.

Conflict of interest

The authors declare that they have no conflict of interest.

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