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Recovery of caprine whey protein and its application in a food protein formulation

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ABSTRACT

This study investigated the recovery of proteins from whey caprine cheese which is mostly discarded as waste. A membrane process including microfiltration and tangential ultrafiltration was used to purify and concentrate the protein solution, reaching a 91.4 g/100 g of protein concentration. The concentrate was then freeze-dried and characterized. The good emulsifying properties, high water and oil holding capacity and the rheological behavior suggested the application of the whey protein concentrate in the formulation of a dressing. Physico-chemical characterization indicated that the samples were similar to a commercial dressing in viscosity, texture, moisture and ash contain. Also the sensory analysis demonstrated a good acceptance mainly in color and flavor of the samples. However, the protein content of the product: 0.97 ± 0.12 g/100 g, duplicated the value of the commercial sample incorporating higher added-value to a product with high consumption.

1. Introduction

The dairy industry is one of the most important sectors of the economy of industrialized and developing countries. Indeed, this industry generates basic human food, such as milk and a variety of derived foods. In general, cheeses are, in terms of volume, the main destination of the processed milk with nearly 45% of total milk production. Thus, approximately 90% of the milk used in the cheese manufacture is eliminated as whey being the most important by-product. However, whey contains about 55 g/100 g of the total ingredients of milk as lactose, soluble proteins, lipids and mineral salts, so it is now considered a valuable product rather than a waste product (Ha & Zemel, 2003; Jelen, 2003; Sanmartín, Díaz, Rodríguez-Turienzo, & Cobos, 2012). Nevertheless, statistics indicate that a significant portion of this by-product is discarded as effluent which creates a serious environmental problem (Aider, Halleux, & Melnikova, 2009). This observation is more noticeable in the case of cheese manufacture from caprine milk, since producing plants are smaller and craft.

In recent years, there has been a renewed interest in caprines dairy products since caprine milk has been recommended as a good substitute for cow's milk, and has become an alternative food due to their nutraceutical and hypoallergenic properties for babies who cannot be breastfed and for children with cow milk allergy (Maduko & Park, 2011). Caprine milk proteins are less allergenic and the fat is more digestible since, fat globules are smaller than that of cow's milk. Another problem associated with the consumption of cow's milk is lactose intolerance, whereas with caprine milk, the increased rate of gastric passage would be one reason why lactose caprine milk intolerance causes fewer problems being insufficient for a manifest colonic fermentation time (Boyazoglu & Morand-Fehr, 2001).

Whey components have different sizes and are forming a homogenous solution in water, as the major component. Thus, the separation and concentration of whey component by means of membrane technology has been previously outlined (Brans, Schroen, Van der Sman, & Boom, 2004; Rinaldoni, Campderrós, Menéndez, & Pérez Padilla, 2009; Sanmartín et al., 2012). The use of microfiltration (MF) and ultrafiltration (UF) is advantageous over

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conventional methods, because it can be performed in one step, with low energy consumption, at low temperatures, without the production of contaminating by-products.

Based on the foregoing, in this paper the recuperation of whey proteins from caprine cheese using membrane technology, and its application in the food formulation was assessed. The composition and functional characteristics were investigated as an essential stage for a successful development of a dressing enriched with caprine whey protein.

2. Material and methods

2.1. Raw material

Caprine whey was obtained from a local cheese-making farm. Caprine cheese whey was obtained from a rennet coagulated cheese that had been produced from pasteurized whole milk (65 °C-15 min). The pasteurized milk was gradually cooled while calcium chloride, thermophile and mesophile yeasts were added. Upon reaching 36 °C, rennet was incorporated, finally sodium chloride was added and the curd was molded and pressed. After 24 h, the mold was removed and the cheeses were salted by immersion. The maturation process started at 8 °C.

After the collection, the whey was passed through a cheese cloth to remove macroscopic impurities and was pasteurized at 63 °C for 30 min. Twenty two liters of whey were processed through UF, in each experience, and the concentrate stream was freeze − dried to obtain the powdered protein concentrate.

2.2. Protein concentrate: microfiltration-ultrafiltration and freeze drying stages

The feed (22 L of caprine whey in each experience) was impelled with a centrifugal pump, first through a frontal flow stainless steel filter, with a pore size of 80 μm (Gora, Argentine). The microfiltration reduces the amount of bacteria and spores acting as a cold pasteurization. Moreover this stage protects the ultrafiltration (UF) membrane from fouling. The UF was performed using Pellicon module (Millipore, Bedford, MA, USA), containing two cassettes of modified polyethersulfone membranes with a molecular weight cut-off (MWCO) of 10-kDa, with a membrane area of 1 m^2. The concentration of proteins by UF was carried out by continuously removing the permeate stream until the desired concentration was achieved. The operating conditions were the following: transmembrane pressure (ΔP) of 420 kPa and a temperature of 11 ± 0.5 °C. The cleaning of the fouled membrane was performed by applying a "Cleaning in Place" (CIP) procedure according to the manufacturer's instructions. At the end of each run, a cycle of water/alkali (0.2 mol equi/L NaOH, pH 13 ± 0.5)/water wash was applied to the membrane at 24 ± 2 °C and at a transmembrane pressure of 100 kPa. Furthermore, a cleaning step using 0.00403 mol/L NaClO solution (commercial grade) was carried out at the same temperature and pressure to ensure sanitation and cleaning. Measurements of normalized water permeability were performed in order to verify recovery of flow through the membrane and the optimal performance during the separation process.

The caprine whey concentrate, obtained by UF was frozen at −40°C and freeze-dried using a lyophilizer (Rificor S.A., Argentina) at a pressure of 100 kPa for 48 h. The temperature of the samples was measured by a temperature sensor.

2.3. Chemical composition

Physicochemical analyses of the feed, permeate and concentrate streams from UF process were determined as follows: pH was measured using a digital pH-meter, (OAKTON Instruments, USA), moisture content by gravimetric method, dry matter by weight difference (AOAC 925.23), ash by incineration (AOAC 945.46); acidity by the official method (AOAC 947.05, 1995); protein content by determination of total nitrogen by the Kjeldahl method using a Digestion Blocks and a semiautomatic Distiller (Selecta, Spain) with a conversion factor of 6.38 (AOAC 991.22); fat content by the Rosse-Gottlieb method (AOAC 933.05); lactose was determined by difference.

All determinations were performed in duplicate.

2.4. Functional characterization of the protein concentrates

Functional properties of food proteins are important in food processing and for food product formulation.

The solubility of protein was determined using the method of Morr et al. (1985). The pH was adjusted between 2 and 8 with either 1 mol equi/L HCl or 1 mol equi/L NaOH, respectively. The solubility was calculated as:

$$S = \frac{(W_{C+R} - W_C)}{(W_{C+S} - W_{C+R})} \times 100 = \frac{W_R}{W_W} \times 100 \quad (1)$$

where W_{C+R} is the weight of the dry residue and crystallizer; W_C is the weight of the crystallizer; W_{C+S} is the weight of the saturated solution (prepared as the Morr method requires) and crystallizer; W_R is the weight of the dry residue (g protein); W_W is the weight of the solvent (g water).

Water holding capacity (WHC) was measured as described by Yu, Ahmedna, and Goektepe (2007). *WHC* (grams of water per gram of protein) was calculated as follows:

$$WHC = \frac{(w_2 - w_1)}{w_0} \quad (2)$$

where w_0 is the weight of the dry sample (g), w_1 is the weight of the tub plus the dry sample (g) and w_2 is the weight of the tub plus the sediment (g).

Oil binding capacity (*OBC*) was determined using the method of Chakraborty (1986). The *OBC* (milliliters of oil per gram of product) was calculated as:

$$OBC = \frac{(V_1 - V_2)}{w_0} \quad (3)$$

where w_o is the weight of the protein concentrate (g), V_1 is the initial volume of vegetable oil (ml) and V_2 is the volume of the supernatant (ml).

Gel strength was determined according to the method described by Chakraborty (1986) and Yu et al. (2007). Protein suspensions containing 2.5 g/100 ml, 5 g/100 ml of protein concentrates were prepared. The pH was adjusted to 3.5; 4.7; 6.1 with 1 mol equi/L NaOH or 1 mol equi/L HCl. Viscosities of these protein suspensions were measured by a Programmable Viscometer (Brookfield, USA). Gel viscosity was determined using a viscometer at different shear rates (10 s^{-1} to 70 s^{-1}) at room temperature (21 ± 0.4 °C). Samples were heated at 90 °C in a shaking water bath for 30 min, and then cooled to room temperature without stirring.

The emulsifying capacity (EC) was determined from the technique described by Yu et al. (2007). When a clear emulsion breakage was observed, the total volume of added oil was recorded and used to calculate the EC as the volume (ml) of oil emulsified per gram of protein sample.

For emulsifying stability determination, emulsions of protein were prepared mixing 0.5 g with 100 ml of distilled water under

constant stirring during 2 min. The pH was varied between 3.5 and 7 with 1 mol equi/L NaOH or 1 mol equi/L HCl. One hundred two and half ml of vegetable oil was added under constant stirring and 0.05 g of sodium azide was also added to prevent microbial contamination. Samples were analyzed with an optical microscope (Arcano XSZ1008N, China) with 40× magnification. The emulsions were photographed for 24 days. Besides, the emulsions were visually examined daily for signs of cremation, oil separation or other physical attributes separating. The height of the spacer layer (*SL*) of oil relative to the total height of the creamed emulsion phase (*E*) was measured as an indicator of the stability of the emulsion. The emulsifying stability was calculated according to the following equations.

$$ES_i = \frac{E_i}{SL_i} \tag{4a}$$

$$ES = \frac{ES_i}{ES_0} \times 100 \tag{4b}$$

where ES_0 is the emulsifying stability in the time = 0 and ES_i represent the emulsifying stability in the time *i*.

Foaming capacity (*FC*) of protein samples was investigated according to the technique described by Chove, Grandison, and Lewis (2007). A volume of 100 ml (V_I) of protein concentrate suspension was blended for 3 min (1000 rpm), poured into a graduated cylinder and the foam volume (V_F) was immediately recorded. Foaming capacity was calculated as:

$$FC = \frac{V_F}{V_I} \tag{5}$$

2.5. Application of the caprine whey protein concentrates in a dressing formulation

Dressings are used for seasoning food and to give more aroma and flavor. These products are frequently used by the food industry to enhance the color and taste of food products (Ma, Boye, Fortin, Simpson, & Prasher, 2013).

The protein concentrates obtained from caprine whey, were applied in the development of dressing formulations. Thus, two types of samples were prepared in triplicate: one without dyes and other with the addition of curcuma. Fig. 1 shows the flowchart of making dressings.

Physicochemical analyses of the dressing samples were performed using the methods described in Section 2.3.

The sugars determination was carried out using a refractometer (ARCANO, China, 0–32° Brix). This measurement is rapid and has a good precision (Van Waes, Baert, Carlier, & Van Bockstaele, 1998).

The apparent viscosities of the dressings with or without curcuma and that of the commercial sample were determined using a viscometer (Haake-VT02, USA).

2.5.1. Texture profile analysis

Instrumental texture profile analysis of the dressings was performed on a Texture Analyzer (TMS-TOUCH, Food Technology Corporation, USA) using a load cell of 50 N and an acrylic cylinder probe (25 mm of diameter). Testing was carried out after the samples had been equilibrated at 12 ± 1 °C. Determinations at 7 days intervals were performed to analyze if any changes occurred in samples with time. Meanwhile, the samples were stored in a refrigerator. The penetration test was performed at a speed of 250 mm min^{-1} with a penetration distance of 10 mm. From the force versus displacement curves (Fig. 2), the following mechanical

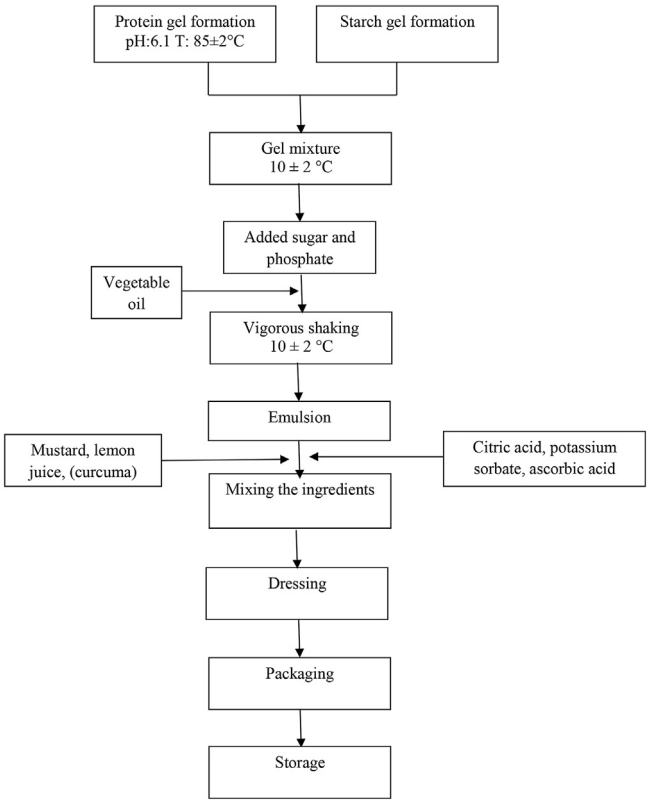

Fig. 1. Flow diagram for manufacturing of a dressing made from goat whey protein concentrate.

properties were determined (Kealy, 2006): hardness (σ_f), which is the highest peak of the curve and represents the force reached at the end of penetration; work of adhesion (Adh), which is the negative area in the figure, representing the work needed to overcome the attractive forces between the surfaces of the probe and the dressing; deformability modulus (DM), which is the slope of the initial linear part of the curve; and work of penetration (W_f), the area under the curve that represents the work required to perform penetration.

2.5.2. Sensory analysis

The samples, with or without curcuma and the commercial one, were tested at 12 ± 1 °C, in a uniformly illuminated room, by 25 semitrained panel members. One hour prior to the evaluations, samples were transferred to closed plastic beakers. The samples were coded with three-digit numbers and were presented in a randomized order. The attributes were estimated on a nine-point scale (from 1 = I like very much to 9 = I dislike very much). The sensory attributes evaluated were color, flavor, taste and consistency. Cookies were provided between samples, to cleanse the palate. Then statistical analysis was performed using the Friedman test, which determines whether the sums of the total orders for each sample differ significantly (Meilgaard, Arbor, Carr, & Civille, 2006).

2.5.3. Analysis of surface color

The surface color was measured by a digital spectrophotometer Mini Scan EZ (Hunterlab, USA) provided with the software. The chromometer was calibrated with the standard white and black color. The results reported are averages of three measurements in each of the dressing samples using CIELAB L*, a*, b* values. *L** value is the lightness variable from 100 for perfect white to zero for black,

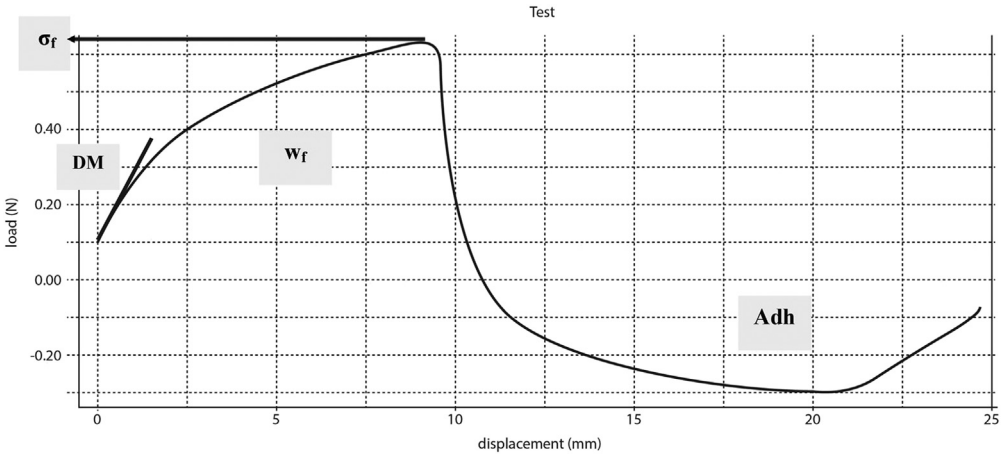

Fig. 2. Force versus displacement curve: σ_f: hardness, Adh: adhesiveness, DM: deformability modulus and W_f: work of penetration.

whilst a^* and b^* values are the chromaticity values, +redness/−greenness and +yellowness/−blueness, respectively (Morales & Van Boekel, 1999).

2.6. Statistical analysis

The obtained data were statistically evaluated by the Tukey–Kramer multiple comparison test in the cases where 2 or more comparisons were considered. Otherwise, the T-test was used, assuming that a $P < 0.05$ was statistically significant (SAS, 1989).

3. Results and discussion

3.1. Concentration of caprine whey protein by MF-UF and freeze drying of the protein concentrate

The profiles of permeate flux in UF obtained showed a characteristic drop in the first 10 min, followed by a trend toward steady state (Fig. 3). A number of phenomena acting simultaneously reduced the permeate flux. Chronologically it is possible to identify three separate phases of flux decline. In the first minute the initial rapid drop in flux is due primarily to concentration polarization. The flux continued to decline, initially rapidly due to protein deposition. It is possible that in UF, the deposition was initially a monolayer which ultimately built up to a complete surface layer. The third phase, a quasi-steady state period where the flux declined slowly, may be due to further deposition of particles or to consolidation of the fouling layer (Marshall, Munro, & Trägardh, 1993). Moreover, the combination of MF and UF produced a lower fouling in the UF membrane, reducing cleaning times and increasing the lifetime of the polymeric membrane. The process was stopped when the desired concentration was achieved, this was at volume concentration ratio (VCR) = 2.79. The VCR was determined as reported by Cheryan (1986), as follows:

$$\mathrm{VCR} = \frac{\textit{Initial feed volume}}{\textit{concentrate volume}} \tag{6}$$

The protein concentrate was freeze-dried, and the nutritive value and organoleptic characteristic are less affected than with other drying methods. This aspect is important for the development of food applications, thus with this treatment, soft and porous powder was obtained.

In order to quantitatively estimate the relative degree of protein concentration in the UF process, the rejection parameter (σ) was calculated. Rejection at any point in the UF process is defined as (Cheryan, 1986):

$$\sigma = 1 - C_P/C_C \tag{7}$$

where C_P and C_C are the solute concentration in the permeate and concentrate, respectively.

The whey protein retention coefficient obtained was $\sigma = 0.91$, corresponding to a high protein retention (91.4 g/100 g).

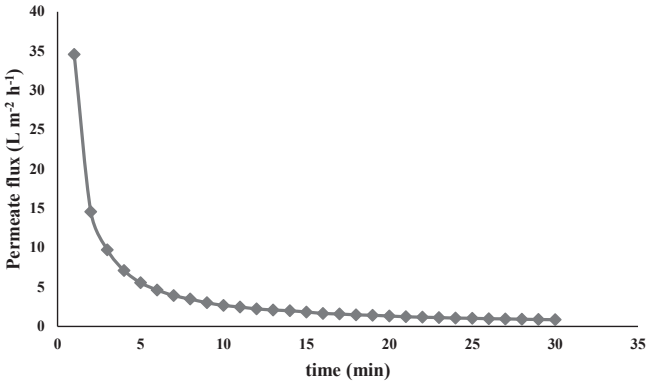

Fig. 3. Permeate flux as a function of time (transmembrane pressure (ΔP) = 420 kPa; temperature = 11 ± 0.5 °C).

3.2. Physicochemical characterization

The results of the physicochemical characterization of the caprine cheese whey (which is the membrane feed solution) and permeate and concentrate streams are shown in Table 1. The permeate is the portion of the feed solution that passes through the membrane and contains basically water, lactose and salts, while the concentrate is the portion of feed solution that is retained on the high pressure side of the membrane. Thus, fats and proteins can be concentrated from the others component of the cheese whey. The composition of the freeze-dried protein concentrate is also shown in Table 1.

The results were similar to that reported by Sanmartín et al. (2012), and Juarez and Ramos (1986). However, it is known that the composition of cheese whey vary with cheese-making procedure and with caprine diet, breed, parity, season, feeding, management, environmental conditions, locality and stage of lactation

Table 1
Proximate composition of feed, permeate, concentrate and freeze-dried concentrate and pH determinations.

Sample	pH	Moisture (g/100 g)	Protein (g/100 g)	Fat (g/100 g)	Ash (g/100 g)	Lactose (g/100 g)
Feed (whey)	5.95 ± 0.07	92.97 ± 0.10	1.28 ± 0.00	0.17 ± 0.01	0.55 ± 0.05	5.03 ± 0.00
Permeate	6.15 ± 0.21	95.29 ± 0.20	0.23 ± 0.04	0.43 ± 0.08	0.41 ± 0.04	3.64 ± 0.00
Concentrate	5.90 ± 0.00	89.71 ± 0.10	2.68 ± 0.04	2.81 ± 0.35	0.51 ± 0.04	4.29 ± 0.00
PC (*)	6.10 ± 0.00	3.52 ± 0.07	23.73 ± 0.03	18.94 ± 0.37	5.99 ± 0.03 g	47.82 ± 0.00

(*)PC: Protein concentrate: processed by UF and freeze-dried.

(Park, Juárez, Ramos, & Haenlein, 2007). Furthermore, the SDS-PAGE technique was used to characterize proteins from feed, permeate and concentrate streams. The results showed that the major whey proteins in the concentrate were: β-lactoglobulin, followed by serum albumin (data not shown), which was in agreement with previous reports (Casper, Wendorff, & Thomas, 1999; Park et al., 2007).

3.3. Functional properties of the whey protein concentrate

From a practical point of view, data about solubility characteristics are quite helpful in determining the optimal conditions of proteins extraction and purification. Solubility is also a good indicator of the potential applications of proteins and influences other functional properties as gelation, emulsifying capacity and foaming formation (Vojdani, 1996; Yu et al., 2007).

Fig. 4 shows that whey proteins were highly soluble at all pH range. This behavior can be attributed to the fact that whey protein surface contains a high number of hydrophilic groups which are hydrated creating a repulsive force sufficient to prevent aggregation via hydrophobic interactions. At pH 4.7–5, whey proteins showed lower solubility because the increment in the attractive forces. Similar results were observed by other researches (Sanmartín, Díaz, Rodríguez-Turienzo, & Cobos, 2013; Casper et al., 1999).

The results of Emulsion capacity (ml of vegetal oil/g of whey concentrate) as a function of pH were: 150 ± 10 (pH = 2); 150 ± 7 (pH = 3.4); 445 ± 15 (pH = 4.7); 210 ± 5 (pH = 6.1); 150 ± 5 (pH = 7). The highest emulsifying ability is at pH 4.7; below and above this pH the emulsifying capacity decreased considerably. As it is known, proteins have low solubility at the isoelectric pH becoming poor emulsifiers. Whey proteins have a good emulsifying ability and stability because they are globular proteins with sufficiently flexible domains in the protein structures, therefore they are able to orient and unfold at the interface decreasing the surface tension and thus the free energy of the system, imparting the desired kinetic stability to dispersions (emulsions or foams), (Rodríguez Patino, Carrera Sánchez, & Rodríguez Niño, 2008). The results have the same behavior of the data described by Sanmartín et al. (2013) for unclarified cheese whey and are in the same order of the values reported by Rodríguez Furlán, Pérez Padilla, and Campderrós (2010).

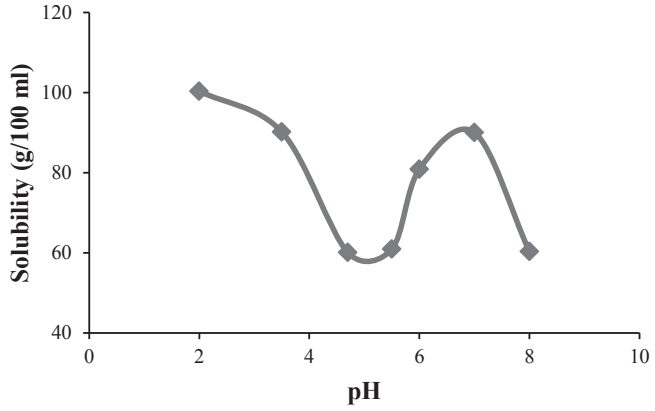

Fig. 4. Solubility of the whey protein concentrate at different pH (temperature = 21 ± 0.4 °C).

The formation and stability of an emulsion is very important in food systems such as salad dressings, ice cream, confectionary or meat products, etc. (Yu et al., 2007).

Emulsion stability (ES), reflects the ability of the proteins to impart strength to an emulsion and resistance to stress. ES results calculated with Equations (4a) and (4b) during 16 days, showed that the whey proteins produced high emulsion stability because they have a high surface activity and an ability to be quickly absorbed into the interface. ES was greater at pH 6 and this result was verified through the obtained images. Table 2 shows the values of emulsion stability (ES) formulated with whey protein concentrates as a function of pH and time and Fig. 5 shows images of emulsions at different days. As expected, drop size increased with time, being the emulsion more unstable.

With respect the foaming capacity, the whey concentrate did not produce foams under the assayed conditions. This result might be explained considering that the lipids are also concentrated during UF process. It is known that small concentrations of lipids strongly alter the foaming properties, since surfactants and polar lipids preclude a favorable conformation of protein films adsorbed on the air–water interface. Our results were in agreement with those reported by Kim, Chism, and Mangino (1987) and with Sanmartín et al. (2013).

The water holding capacity (*WHC*) plays an important role in the texture quality of various foods, e.g. soups, ground meat, dressing, sauces and baked products. The water adsorption without protein dissolution, leads to swelling providing properties such as consistence, thickening, viscosity and adherence (Yu et al., 2007). The results indicated that for pH 3.5; 4.7 and 6 the *WHC* was: 1.09 ± 0.05, 1.38 ± 0.02 and 4.3 ± 0.03 (ml of water/g of product) respectively. The last value is greater than those reported for milk and soy protein concentrates (Rodriguez Furlán, Rinaldoni, Pérez Padilla, & Campderrós, 2011).

Table 2
Emulsion stability (ES) of whey protein concentrate at different pH.

Day	pH 3.5	pH 6	pH 7
	ES (ml/100 ml)	ES (ml/100 ml)	ES (ml/100 ml)
1	100 ± 0.02	100 ± 0.02	100 ± 0.02
2	76.20 ± 0.02	25.56 ± 0.34	22.74 ± 0.07
3	10.75 ± 0.90	1.28 ± 0.25	1.45 ± 0.34
4	2.22 ± 0.35	0.92 ± 0.25	0.96 ± 0.32
5	2.22 ± 0.30	0.85 ± 0.30	0.83 ± 0.34
6	1.42 ± 0.30	0.78 ± 0.09	0.71 ± 0.09
7	1.42 ± 0.02	0.72 ± 0.36	0.60 ± 0.35
8	1.36 ± 0.32	0.65 ± 0.25	0.60 ± 0.34
9	0.96 ± 0.28	0.51 ± 0.30	0.54 ± 0.30
16	0.62 ± 0.30	0.51 ± 0.25	0.53 ± 0.30
17	0.48 ± 0.24	0.49 ± 0.28	0.37 ± 0.30

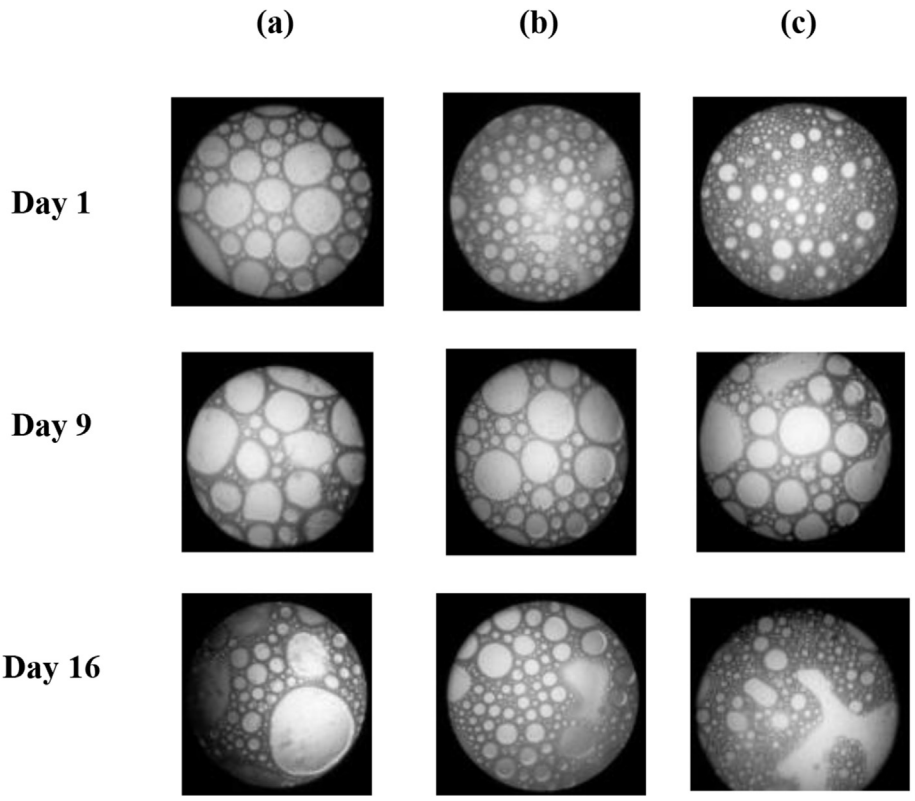

Fig. 5. Emulsion stability for the whey protein concentrates as a function of time and pH: (a) pH 3.5; (b) pH 6; (c) pH 7 (temperature = 21 ± 0.4 °C).

The oil binding capacity (*OBC*) of proteins is significant in the formulation of fried products and for taste conformation, moreover decreases the development of oxidative staling increasing the stability during storage. The result obtained in this study was *OBC* = 2.54 ml of oil/g of product, that is in agreement with values previously obtained for other protein concentrates (Rodriguez Furlán et al., 2011).

With regard to the rheological properties of the whey protein concentrate, Fig. 6 shows the results obtained. The samples exhibited a pseudoplastic behavior, being sensitive to pH. Gel formation takes place because of a controlled aggregation of the protein molecules after cooling, forming a tridimensional matrix that confines the liquid (Yu et al., 2007). Consistency and flow indexes are of practical value affecting food taste and texture but are also useful for engineering design and for mechanical handling of fluid materials. The Power Law model was applied to describe flow behavior of PBP, determining the flow behavior index, *n*, and the consistency index, *K*. The *n* values were effectively <1, (pseudoplastic behavior). At pH < 7, an increase in the consistency index and in the apparent viscosity of the solutions was obtained. This can be explained considering that the bonds among the protein molecules increase the viscosity or the consistency index of the solutions as a function of the pH (Gauche, Vieira, Ogliari, & Bordignon-Luiz, 2008).

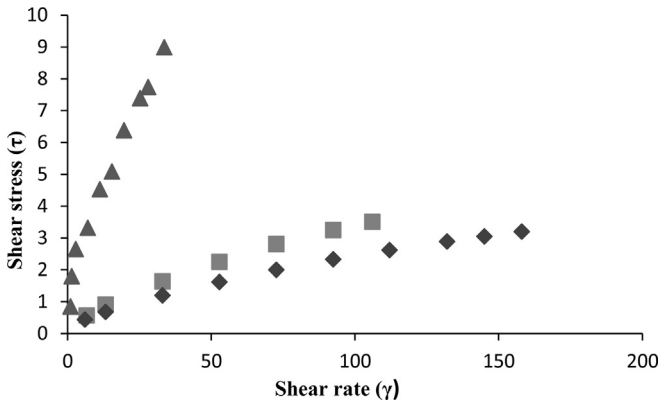

Fig. 6. Viscosity of gels prepared from caprine whey protein concentrate at 5% at different pH: ♦3.5; ■4.7; ▲6.1 (temperature = 21 ± 0.4 °C).

3.4. Analysis of the dressing samples

The physicochemical determinations are shown in Table 3. The results were compared with a commercial dressing. The protein content in processed dressings for both samples with or without colorant was doubled respect to the commercial sample. The lipid content was higher in the dressing with whey protein concentrate, although this content was still considered low. With respect to ash content, apparent viscosity and pH, the values were similar to the commercial ones. The concentration of chloride ion was in accordance with the values established by the Código Alimentario Argentino (CAA): <1.6 g/100 g.

For this composition, a portion of 12 g of dressing provides 32 calories. This value is in agreement with the declared value of different commercial low calorie dressings.

3.5. Surface color analysis

The results of color measurements on dressing samples are shown in Table 4. The commercial product and dressing enriched with whey cheese protein concentrate, showed a high L^* value (higher than 80) which reflects the degree of lightness. The a^* value showed a slight deviation towards the negative values. The b^*

Table 3
Physicochemical determinations in the samples compared with a commercial dressing.

Sample	Viscosity (cp)	Protein (g/100 g)	Moisture (g/100 g)	Fat (g/100 g)	Ash (g/100 g)
Dressing	14266.67 ± 642.90	0.96 ± 0.00	61.44 ± 1.83	24.11 ± 1.08	1.87 ± 0.05
Dressing (c)	14833.33 ± 1527.50	0.98 ± 0.23	61.83 ± 1.27	24.29 ± 1.20	1.79 ± 0.02
Commercial	15000.00 ± 353.55	0.45 ± 0.12	70.80 ± 0.99	14.70 ± 1.20	2.20 ± 0.04

(c): with colorant.

Table 4
Surface color of the samples compared with a commercial dressing.

	L*	a*	b*
Dressing	81.12 ± 1.16	3.46 ± 0.80	24.88 ± 1.83
Dressing (c)	80.50 ± 0.34	−9.08 ± 0.50	52.90 ± 5.67
Commercial	84.41 ± 1.84	−3.16 ± 0.42	34.07 ± 0.95

(c): with colorant.

positive value indicated the degree of yellowness. The dressing with curcuma exhibits b* values higher than the control and the samples without colorant had lower values.

3.6. Texture determination

The results of texture determinations for the dressings prepared in the lab (with or without curcuma) and the commercial samples were, respectively: hardness: 0.625 ± 0.08 and 0.86 ± 0.0 (N); work of adhesion: 3.56 ± 0.43 and 3.87 ± 0.62 (Nmm); work of penetration: 4.33 ± 0.51 and 10.09 ± 0.42 (Nmm) and deformability modulus: 0.135 ± 0.02 and 0.24 ± 0.00. Formulated dressings presented texture parameters slightly lower than commercial sample, however the hardness and adhesiveness of developed samples are quite similar to those reported for salad dressings prepared with pregelatinized potato starch (Bortnowska et al., 2014).

3.7. Sensory assessment

The assessment on samples considering the attributes of color, flavor, consistence and overall acceptance, are shown in Fig. 7. Results show that the order of preference by the panelists was: commercial dressing > dressing without curcuma > dressing with curcuma. Regardless of being in second order, the developed dressing without colorant, presented a very good acceptance mainly emphasizing color and flavor, as shown in figure.

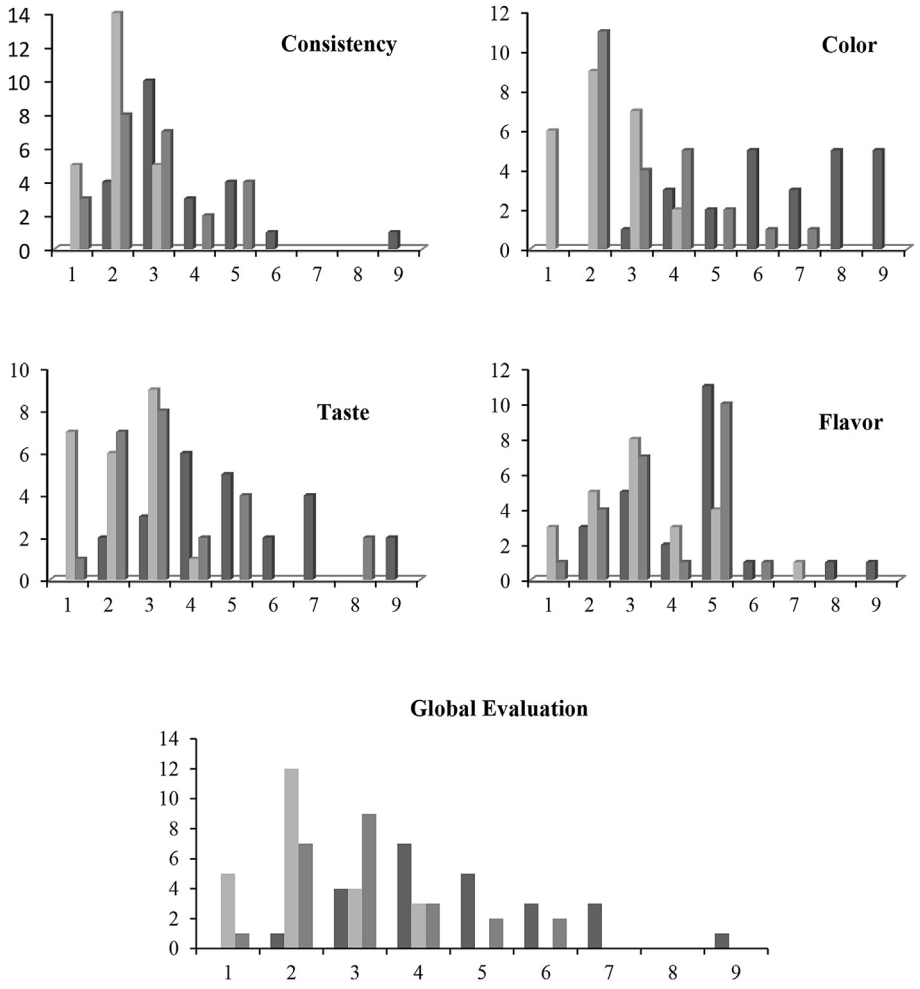

Fig. 7. Sensory analisis. 1: I like very much; 2: I like; 3: I like moderately; 4: I like little; 5:I neither like nor dislike; 6: I dislike little; 7: I dislike moderately; 8: I dislike a lot; 9: I dislike very much. ■Dressing without curcuma; ■Dressing with curcuma ■Comercial control sample.

4. Conclusions

A protein concentrate from waste of a productive activity such as caprine cheese elaboration was obtained by means of membrane technology. The procedure employed allowed protein retention of 91.4 g/100 g. The concentrate was freeze–dried and the functional and physicochemical properties of the obtained powder were characterized. Functional properties profiles for caprine whey proteins were in general pH-dependent, with the lowest solubility at pH 4–6; at this pH range the best emulsifying capacity and stability was obtained. The results from rheological properties indicated that the whey concentrate become a suitable candidate for formulations that require gelation. According to the properties evaluated and the behavior presented, the caprine protein concentrate was applied in the formulation of a dressing.

The product developed presented similar physicochemical characteristics to the commercial dressing as pH, ashes, viscosity, texture and color. Sensory analysis also showed that the dressing had a good acceptability. However the principal nutritional advantage is that the samples contained twice of the protein content, and although fats content was also higher, the dressing continues corresponding to a reduced fat product. The main environmental benefit is the utilization of the liquid effluents of cheese-making industry, which bare high DBO5, so they cannot be discharged without a previous depuration treatment. To this regard, the conversion of these effluents into added-value ingredients for food industry is interesting.

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