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INTERFACIAL AND FOAMING PROPERTIES OF TWO TYPES OF TOTAL PROTEOSE-PEPTONE FRACTIONS

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**INTERFACIAL AND FOAMING PROPERTIES OF TWO TYPES OF TOTAL
PROTEOSE-PEPTONE FRACTIONS**

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Abstract

Total proteose-peptone (TPP) fractions were extracted from skimmed milk (UHT) and whey protein concentrate (WPC) on a laboratory scale. Protein solutions (0.1, 0.5 and 1 % w/w) were characterized as function of pH: 4.0, 4.6-4.7 (native pH) and 7.0. Their foaming capacities and stabilities were studied. Beforehand, the surface properties that govern them were investigated, notably the kinetics of adsorption and mechanical properties of monolayer films at the air-water interface involved in the formation and the stability of foams respectively. The TPP extracted from skimmed milk showed the lowest values as well as a significant reduction in surface tension and presented a good mechanically resistant film. The TPP extracted from WPC presented a better foaming capacity and stability which was unexpected. However, foaming properties and surface properties of TPP fractions depended on the pH. The considerable influence of extraction source and method on proteose-peptone's properties were highlighted.

Keywords: Proteose-peptone, whey protein concentrate, kinetic adsorption, monolayer film, foaming properties, foamscan

Introduction

Foams are a subject of strong interest in a large number of industries where they play a crucial role. In the food industry, a foaming formulation involves the use of surface-active agents. During the foaming processes, these agents adsorb rapidly and form a film at the surface of gas bubbles. Surface-active agents must simultaneously give abundant and stable foams. Many researches are focused on the development of novel ingredients, including proteins which can be used as foaming agents. Food processing industries use these protein ingredients to improve the functional properties of a wide range of formulated food (Cassiani et al., 2011). Among food proteins, whey proteins are considered as important and valuable ingredients due to their high nutritional and functional properties (Blecker et al., 1997; Mladen et al., 2009). These features confer to whey proteins ingredients high foaming and stabilizing properties.

Among the whey components the total proteose-peptone fraction (TPP) could be of interest. Indeed the TPP is a minor fraction of the heat-stable and acid-soluble protein which is found in whey (Blecker et al., 2005). According to the literature, this fraction has interesting functionalities such as surface properties, emulsifying properties and foaming properties (Shimizu et al., 1989; Innocente et al., 1998a, 1998b).

However, previous works on the foaming property of the milk's TPP fraction are controversial. Some authors such as Zhu and Damodaran (1994) have shown a negative effect of the TPP on the foam property (foam stability) produced by whey due to certain competitive actions of other proteins. On the other hand, the TPP fraction is considered responsible of milk foaming capacity due to its component PP3 (Girardet and Linden, 1995). Moreover, most of studies reported in the literature concerns the TPP extracted from milk.

49 In the light of these considerations, this study attempted to provide new information
50 about the foaming properties of TPP, especially the TPP extracted from whey. To reach this
51 goal, two types of TPP fractions were extracted in this work. The first one was extracted from
52 skimmed milk using a classic method according to Pâquet et al (1988) and the second was
53 extracted from whey protein concentrate according to a procedure which is feasible on an
54 industrial scale.

55 The interest of this work is to study the TPP extracted from whey protein concentrate
56 (78 % of protein), a commercially available by-product of cheese processing. The use of this
57 alternative source could allow an increased TPP production for industrial applications. Foam
58 properties were characterized for possible use in food applications requiring foam formation
59 such as whipped cream, ice cream, cakes and desserts.

60 In the literature, SDS-PAGE electrophoresis was used to characterize the TPP fraction's
61 components according to Laemmli's method (Pâquet et al., 1988). However several others
62 separation techniques were also used including liquid chromatography which allow a good
63 separation of the TPP's components. The hydrophobic interaction was most often used to
64 separate the TPP due to the hydrophobicity of some major components. In our case, Tricine
65 SDS-PAGE electrophoresis according to schägger (2006) was used to characterize the TPP,
66 due to it's high resolution, especially for the small proteins.

67 The aim of this study was to determine the ability of TPP fractions to form and stabilize
68 foams at several protein concentrations, at various pH, and to highlight the influence of the
69 extraction method on these properties.

1. Materials and methods

1.1. Extraction of total proteose-peptone fractions

1.1.1 Extraction from milk

Milk total proteose-peptone fraction (milk TPP) was extracted from UHT skimmed milk according to the procedure described by Pâquet et al. (1988) with some modifications. Three batches of ten litres of commercial skimmed milk (Everyday, Colruyt, Belgium) were used to extract the TPP. The process consisted in heating one litre of skimmed milk at 90 - 95 °C during 30 min and then cooling it down in an ice bath to 20 °C during 40 min. pH was then adjusted at 4.6 with 1M HCl to induce isoelectric precipitation. Samples were centrifuged at 5000 g for 30 min at 20 °C (Centrifuge Beckman Model J2-21, Indianapolis, USA). Ammonium sulfate (304 g) was added to the supernatant (800 mL) to obtain a half-saturated solution that was then shaken and centrifuged (5000 g for 10 min at 20 °C). The pellet was dispersed, exhaustively dialyzed and finally lyophilized. The TPP yield was stored at 4 °C until analysis.

1.1.2 Extraction from whey protein concentrate (WPC)

Whey protein concentrate (WPC) (Lacprodan 80) was obtained from Arla Foods Ingredients (Viby J, Denmark). 2.85 Kg of commercial WPC were used. WPC was dispersed into distilled water (95 g.L⁻¹) by stirring at room temperature for 2 hours to ensure good dispersion. Whey total proteose-peptone (WPC TPP) was then extracted from the dispersion using the same procedure described for extraction from milk without the ammonium sulfate addition. The TPP yield was stored at 4 °C until analysis.

1.2. Chemical composition of TPP

The TPP fractions obtained were analyzed for ash (AOACI, 2000), lipid by modified mojonnier method (AOACI, 2000) and lactose (Miller, 1959). The determination of protein content was performed by the Lowry method as described by Lowry et al. (1951).

1.3. Electrophoretic Analysis using Tricine-SDS-PAGE

TPP molecular weight distribution was evaluated by Tricine-SDS-PAGE electrophoresis following the method of Schagger (2006). The Tricine-SDS-PAGE was performed with a vertical electrophoresis apparatus model 2001 (Amersham-Pharmacia, Uppsala, Sweden) with a 16 % polyacrylamide separating gel (16 % T, 3 % C where T is the total concentration of acrylamide/bis-acrylamide monomers and C is the amount of crosslinker relative to the total concentration) and thickness of 1.5 mm. Tricine-SDS-Page uses two buffers and offers a high resolution, especially in the small protein and peptide range. The electrophoresis buffers were tris-HCl buffer (anode buffer) and Tricine-tris buffer (cathode buffer). 500 µl of sample (1-3 % w/v of proteins) were treated with a equivalent volume of sample buffer (150 mM Tris-HCl, pH 7.0, 12 % SDS; 6 % mercaptoethanol, 30 % glycerol, 0.05 % Coomassie blue), and then heated at 37 °C for 15 min before electrophoresis. Electrophoresis was performed at an initial voltage of 30 V for stacking and at a constant voltage of 90 V for separation. The protein bands were fixed in a solution consisting of 50 % methanol, 10 % acetic acid, and 100 mM ammonium acetate for 60 min, before staining by 0.025 % coomassie dye in 10 % acetic acid for 24 h. The gel destaining was performed in 10 % acetic acid.

1.4. Dynamic Drop Volume Method

TPP samples were prepared in ultra-pure water (ultra-pure water system Milli.Q50, Millipore). TPP solutions of 0.1, 0.5 and 1% (w/w) were prepared at various pH values: 4.0, 4.6-4.7 (native pH) and 7.0. Automated drop volume tensiometer TVT1 (LAUDA, Königshöfen, Germany) was used to perform dynamic measurements for surface tension

measurements at air-water interface. The experiments resulted in the measurement of surface tension as a function of the drop formation time (Innocente et al. 1998). All experiments were performed at $25 \pm 0.5^\circ\text{C}$. Each measurement was repeated three times. Equilibrium interfacial tension (γ_e) and the initial adsorption rate (v) were determined by extrapolated values of γ vs. $t^{-1/2}$ at $t \rightarrow \infty$ and the tension (γ) versus time (t) curve slope at initial time (t_0), respectively (Blecker et al., 2002; Innocente et al., 2011).

1.5. Adsorption Kinetics Recording

The surface tension-time dependence of TPP solutions was measured with the automatic drop tensiometer TRACKER (IT Concept, Longessaignes, France) forming a rising protein solution bubble of at the tip of 5 μL a curved capillary in an empty cell (containing air). The surface tension was measured and recorded every second. All measurements were performed at $25 \pm 0.5^\circ\text{C}$.

1.6. Mechanical properties of monolayer film

Protein samples were prepared by dissolving the lyophilized material in ultra-pure water (ultra-pure water system Milli.Q50, Millipore). Protein solution (1 mg.mL^{-1}) were characterized at various pH values: 4.0, 4.6-4.7 (native pH) and 7.0. Measurements of the surface pressure (π) versus surface area were performed on Langmuir-type film balance LFW2 (LAUDA GmbH, Königshöfen, Germany) of which the principle and the experimental condition were described by Innocente et al. (1998). Schematically this technique involved the measurement of the surface tension of an aqueous surface under different compression conditions in the presence and absence of a surface monolayer, and may be described by the following equation:

$$\pi = \gamma_0 - \gamma, \quad (1)$$

where π is the surface pressure, γ_0 and γ are the surface tension of the clean surface and the surface containing the monolayer, respectively. The elasticity (ϵ) of the protein film at the air-

water interface, defined as the variation in surface pressure for a variation in the surface unit area, was then calculated for every point of the isotherm π/A by means of the following equation:

$$\varepsilon = - A (d\pi/dA), \quad (2)$$

where $d\pi/dA$ is the surface pressure derivative in surface area (Damodaran, 1994). All experiments were performed at $25 \pm 0.5^\circ\text{C}$.

1.7. Foaming properties

Foaming capacity and foam stability of total proteose-peptone were determined with a Foamsan (IT Concept Instrument, Longessaignes, France). The system includes a transparent column of glass, with at its base a porous frit through which the gas is injected. The volume of liquid and foam are measured with a conductivity meter, composed of a series of two electrodes located at the base of the column and four electrodes placed at the top of the column. 25 ml of protein solution was aerated at a flow of $100 \text{ mL}\cdot\text{min}^{-1}$. The evolution of the foam was monitored to assess foam stability and its height was continuously measured by image analysis. A fritted glass with a porosity of 4 (P4) was used and the aeration time was 60 seconds. Measurements were performed at 25°C . The foam capacity (FC) was determined by:

$$\text{FC} = V_f/V_g, \quad (3)$$

Where V_f is the final foam volume and is V_g the final gas volume injected. Foam stability (FS) was determined as the time needed to drop to half the final foam volume ($T_{1/2}$).

Measurements were performed in triplicate with fresh solution. Protein solutions were prepared according to the sample preparation of the surface tension study. The speed of decreasing (Sd) after switching off the bubbling was calculated using equation 4.

$$(\text{FV}_{450\text{s}} - \text{FV}_{60\text{s}}) / (450 - 60)$$

$$Sd = \frac{\quad}{60} \quad (4)$$

1.8. Statistical analysis

The data shown are the average of triplicate values. Statistical analyses were carried out using a SPSS for windows, version 11.0 (SPSS Inc., 1999). The data were subjected to analysis of variance (ANOVA) using the general linear model option (DUNCAN test) to determine significant differences between samples ($P < 0.05$).

2. Resultats and Discussion

Total proteose-peptone (TPP) fraction is usually extracted from milk, with a yield around 1 g.L⁻¹ (Mati et al., 1991). In this study, the modification of Pâquet's procedure allowed to increase the quantity of TPP extracted from milk to 1.56 g.L⁻¹ of milk (i.e. 1.56 g / 130 g dry matter). The extraction of TPP from the alternative source WPC (78 % of protein) reached 19.13 g / 95 g of WPC. The use of WPC allowed to increase the TPP production by a process potentially transposable on an industrial scale. However, the composition of TPP fractions (Table 1) showed a fundamental difference between the two types of TPP in terms of protein content. Milk TPP contains more protein than WPC TPP (79.15 % versus 65.20 % of protein). The lipid content of milk TPP was relatively greater than in WPC TPP, while the lactose content was more important in WPC TPP than milk TPP. It should be noted that lactose represents a big part of nonprotein component that does not affect the interfacial properties of the extract but could instead affect the foam stability (Zhu and Damodaron, 1994).

The protein analysis on milk TPP by Tricine SDS-PAGE (Figure 1), presented the same bands as described in the literature, notably component PP3 also named LP28 (28 kDa) according to (Kanno, 1989), LP18 (high hydrophobic component of 18 kDa) (Sorensen and

Petersen, 1993), component PP5 (14.3 kDa) (Kollar and Brunner., 1970) and component PP8S (9.9 kDa) (Kollar and Brunner., 1970). The band corresponding to component PP8 F as referred to by Kollar and Brunner (1970) was not observed on the gel due to its very low molecular weight (4 kDa). The LP18 (18kDa) was the high hydrophobic component of the FHPP of TPP. LP18 hydrolyzed by plasmin from LP28 in milk was absent in the extract of WPC (WPC TPP). However, a difference in thickness and intensity was observed with regard to the bands PP5 and PP3. Thus, the PP3 band in milk TPP appears stronger and more intense than the PP3 band in WPC TPP. The PP5 band was thinner in milk TPP than WPC TPP. In view of these observations, it could be said that milk contained more PP3 and less PP5 compared to WPC TPP, this depends on milk's evolution before undergoing heat treatments such as UHT or whey processing.

2.1. Dynamic surface tension

Adsorption kinetics at the air-water interface of TPP fractions extracted from skimmed milk and WPC were compared by using dynamic surface tension technique. Many factors may affect this property at the interface such as concentration, pH, and temperature. Among these, the concentration and pH were specifically considered. Therefore, Figure 2 represents the surface tension as a function of drop formation time for both different fractions at 1 % (w/w), and at various pH. Surface tension value decrease with the increase in drop formation time, because molecules have more time to position themselves uniformly at the interface where they can develop their surfactant activity (Innocente et al., 2011). At all tested concentrations and pH, the surface tension reduction was more pronounced for milk TPP in comparison to WPC TPP. This suggested that milk TPP had a higher surface activity than those extracted from WPC. This difference in behavior could be related to the hydrophobic fraction commonly called HFPP which contains LP18 and LP28 in milk TPP according to the

electrophoresis. Moreover, it was demonstrated that the surface-active properties of the TPP fractions are in part governed by the physicochemical properties of PP3 such as aggregation properties and surface hydrophobicity (Innocente et al., 1998a; Piquet et al., 1988). Therefore, the relative percentage of PP3 in each fraction might certainly explain the lower interfacial activity of WPC TPP compared to milk TPP.

The discussions hereafter are focused on the 1 % (w/w) solutions because the difference between the samples was not significant at 0.1 % and 0.5 % ($P \geq 0.05$). It appeared that the milk TPP lowered the surface tension when the pH increased. Conversely, for WPC TPP the lowest value of surface tension was observed at pH 4.0 or native pH (4.7). These differences are due to the composition of each fraction. The LP18 observed in milk TPP composition could be at the origin of these behaviors with regards to pH. Indeed, LP18 comprises four isoelectric isoforms (pI 5.0 - 8.0) (Inagaki et al., 2010). At pH 7.0 milk TPP presented a net charge because this pH is in this range, which explained the lowest surface tension value at pH 7.0. Whereas, the pI of TPP is 4.0 to 5.0 according to Pâquet et al. (1988). So, WPC TPP presented a net charge at pH 4.0 and native pH (4.70), which explained the lowest surface tension values obtained at these pH compared to pH 7.0.

The analysis of adsorption kinetic curves was quantified by determining the initial adsorption rate and equilibrium surface pressure (Table 2) to explain the reduction of surface tension. Thus, the initial adsorption rate is equivalent to the slope of the tangent to the curve at the start of the kinetics; it characterizes the velocity at which molecules lower the surface tension at the beginning adsorption. This initial adsorption rate has been determined using the automatic drop tensiometer tracker (Table 2) which was used as a complement to TVT. The initial surface tension value at $t = 0$ corresponding to the water surface tension, was equal to 72.00 mN.m⁻¹. Equilibrium surface pressure value ($\pi_e = \gamma_0 - \gamma_e$, where γ_0 is the initial surface tension and γ_e is the equilibrium surface tension) characterizes the maximum reduction of

surface tension induced by the surfactant molecules, in our case the dispersion of the proteose-peptone. The highest values of initial adsorption rate and equilibrium surface pressure were observed for milk TPP ($P < 0.05$). Equilibrium pressure values obtained correspond to a reduction of the initial surface tension value of 32 to 35 % for milk TPP and 29 to 30 % for WPC TPP. This indicated that milk TPP caused a rapid reduction of interfacial tension that reached the equilibrium values faster compared to WPC TPP. Many authors have shown that the adsorption rate is correlated with the foaming capacity of proteins (German et al., 1985; Dagorn-Scaviner, 1986) and the development of an important surface pressure is required to obtain good stability of dispersed systems (Nakai et al., 1980). Overall, these findings suggested a better foaming capacity for milk TPP compared to WPC TPP.

2.2. Study of monolayer films

Mechanical properties of the monolayer films formed by TPP fractions were investigated in addition to the adsorption kinetics study. This was done using a Langmuir film balance to determine the compression isotherms in order to understand the foaming properties. The compression isotherms obtained at the air-water interface represent the surface pressure against surface area (square meter per milligram of proteins). During the compression of film, the surface pressure increases.

In generally, when the film molecules undergo a compression, the surface area occupied per mg of protein decreases. The surface pressure increased from a value A_0 (initial area), linearly up to a transition zone which was observed around an inflection point. After this, the surface pressure increased to a maximum value at the end of compression. Milk TPP formed films with a higher mechanical resistance with regard to surface pressure, compared to WPC TPP. The compression isotherms were recorded at different pH, it is clear from Figure 3 that they present the same profiles at the considered pH. The surface pressure changed with the

pH. Monolayer films of milk TPP presented a better resistance at pH 7.0 than at pH 4.0, and inversely for the WPC TPP ($P < 0.05$). These results are in agreement with those of the kinetics of adsorption at air-water interface.

The compression isotherms reflect the mechanical properties of the monolayer whereas the stability of the film is a phenomenon linked to the forces of cohesion in the monolayer as well as the intermolecular interactions within the film, and between the molecules of the film and the aqueous phase. These interactions influence the mechanisms governing the film instability leading to a break (Baglioni et al., 1980). Hence, the film elasticity which measures the film resistance towards a change in surface can be considered as a parameter quantifying the intermolecular interaction and the film-subphase interaction (Rodriguez-Patino et De la Fuente Feria, 1995) allowing to explain the stability mechanism of film. The elasticity was determined in the area above the transition zone because it corresponds to the location of the condensed film during the film stability (Gaines, 1966). Maximum elasticity values obtained at the different pH are shown in Table 3. The highest values were observed for the TPP WPC spread at pH 4 (13.15 mN.m^{-1}), whereas milk TPP obtained its highest value at pH 7.0 (11.62 mN.m^{-1}). This trend inversed has already been mentioned for adsorption kinetics and compression isotherms. In view of the results presented in Table 3, WPC TPP films were more elastic than milk TPP film except at pH 7.0 ($P < 0.05$). The molecules of WPC TPP film were more resistant to conformational change compared to those of milk TPP film except at pH 7.0. Such a property is required for good foam stability (Poré, 1976). The differences between milk TPP and WPC TPP films could again be explained by considering differences in their compositions.

2.3. Foaming properties

Foam capacities (FC) of proteose-peptone fractions at 1 % (w/w) were compared at various pH as depicted in Figure 4. Generally, the foaming capacity increased with increasing concentration of protein. The foaming capacity of milk TPP was lower than that of WPC TPP at all pH studied. The milk TPP foaming power increased with the increasing of pH, whereas the WPC TPP foaming power decreased with increasing pH. This effect of pH on foaming capacity of each fraction was correlated with the adsorption rate obtained for each fraction (see paragraph 2.1). This is in accordance with German et al (1985) and Dagorn-Scaviner (1986) which showed a correlation between the adsorption rate and the foaming capacity.

The foaming inability of milk TPP can be explained by the quantity of fat in its composition. The quantity of lipid is greater in milk TPP than in WPC TPP (Table 1). The presence of small lipid quantities can have a strong destabilizing effect on foaming (Huppertz, 2010). A lower FC of milk TPP induced a collapse of the air bubble during foam formation. This is probably due to the weak mechanical strength of the lipid-protein interaction.

Foam stability (FS) was characterized by the half-life of foam volume. The effect of pH on this parameter is represented in Figure 5. As in the case of foaming capacity, the effect of pH on foam stability was correlated with the surface pressure obtained in Adsorption kinetics study. This was mentioned by Nakai et al. (1980) which say that the development of an important surface pressure lead to a good stability of dispersed systems.

In general, the increasing concentration of TPP improved foam stability (data not shown). WPC TPP capacity to stabilize foam was greater compared to milk TPP (at all pH), as the time needed to reduce the foam volume to half of the maximum volume ($T_{1/2}$) was higher. This indicates the higher resistance of WPC TPP film to the coalescence of bubbles. The evolution of foam volume of TPP fraction at 1 % during the first 450 seconds as function of pH is represented in Figure 6. The difference in foam behavior was demonstrated by the speed of decrease after switching off the bubbling (Table 4). The highest value of decrease

speed was observed for milk TPP foam; this indicated a greater ability to stabilize for WPC TPP. The better foaming properties of WPC TPP were essentially due to the lower quantities of lipids in WPC TPP composition, as it is well known that lipids destabilize foam (Huppertz, 2010).

3. Conclusion

Variations in functional and surface properties of the two TPP fractions are due to several factors (heat treatments, UHT or whey processing), extraction source, extraction method and the composition of each fraction (lipids and proteins). Milk TPP exhibited a higher surface activity and a better monolayer film resistance to mechanical disturbances. Whereas the best foaming properties were exhibited by WPC TPP. This best performance of WPC TPP compared to milk TPP is due to the lipid fraction of milk TPP which prevents them to foam. It is conceivable they could both be used as surface-active agents in food applications requiring foam formation. On the other hand, the extraction from WPC would be interesting because it is advantageous in terms of high TPP production yield and economical compared to TPP extracted from milk.

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Figure 1

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Figure 2
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Figure 2: Surface tensions as a function of time for 1 % (w/w) of total proteose-peptone fractions (Milk TPP (♦) and WPC TPP (○)) using the drop volume method. (A) pH 4.0, (B) native pH, and (C) pH 7.0.

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Figure 4
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Table 1: Composition (% of dry material) of freeze dried TPP fractions extracted from WPC and milk.

	WPC TPP	Milk TPP
	(Dry matter : 91.40 % ± 0.04)	(Dry matter : 91.75 % ± 0.10)
Protein	65.20 % ± 0.03 ^a	79.15 % ± 0.10 ^b
Ash	3.50 % ± 0.15 ^a	2.85 % ± 0.13 ^a
Lipid	4.60 % ± 0.08 ^a	6.55 % ± 0.05 ^b
Lactose	26.22 % ± 0.09 ^b	10.52 % ± 0.07 ^a

^a Values within the same line followed by the same superscript letters do not differ significantly at P < 0.05 (Duncan test). Mean of triplicates.

Table 2: Equilibrium surface pressure (π_e) and Initial adsorption rate (V) at air-water interface for total proteose-peptone fractions at 1 % (w/w) of protein at various pH.

	pH	V (mN.m ⁻¹ .s ⁻¹)	π_e (mN.m ⁻¹)
Milk TPP	4.00	11.39 ± 0.12 ^d	23.39 ± 0.24 ^d
	4.67	15.60 ± 0.15 ^e	24.11 ± 0.03 ^e
	7.00	17.37 ± 0.19 ^f	24.88 ± 0.12 ^f
WPC TPP	4.00	9.61 ± 0.18 ^c	21.66 ± 0.09 ^c
	4.70	8.80 ± 0.09 ^b	21.29 ± 0.13 ^b
	7.00	7.95 ± 0.26 ^a	20.94 ± 0.06 ^a

^a Values within the same column followed by the different superscript letters are differ significantly at P < 0.05 (Duncan test). Mean of triplicates.

Table 3: Maximum elasticity value (ϵ) of total proteose-peptone fractions films at various pH.

	pH	ϵ (mN.m ⁻¹ .s ⁻¹)
Milk TPP	4.00	10.19 ± 0.01 ^b
	4.67	10.22 ± 0.27 ^b
	7.00	11.62 ± 0.12 ^c
WPC TPP	4.00	13.15 ± 0.09 ^c
	4.70	12.32 ± 0.14 ^d
	7.00	9.05 ± 0.09 ^a

^a Values within the same column followed by the same superscript letters do not differ significantly at P < 0.05 (Duncan test). Mean of triplicates.
 $\epsilon = - A (d\pi/dA)$.

Table 4: Speed of decreasing (cm³.min⁻¹) after switching off the bubbling of total proteose-peptone fractions foams at 1 % (w/w) at various pH.

	pH	Speed of decreasing (cm ³ .min ⁻¹)
Milk TPP	4.00	8.84 ± 0.72
	4.67	9.16 ± 1.06
	7.00	12.06 ± 1.55
WPC TPP	4.00	5.75 ± 0.77
	4.70	4.15 ± 2.99
	7.00	7.40 ± 0.31

Means of triplicates.

ABSTRACT

Total proteose-peptone (TPP) fractions were extracted from skimmed milk (UHT) and whey protein concentrate (WPC) on a laboratory scale. Protein solutions (0.1, 0.5 and 1 % w/w) were characterized as function of pH: 4.0, 4.6-4.7 (native pH) and 7.0. Their foaming capacities and stabilities were studied. Beforehand, the surface properties that govern them were investigated, notably the kinetics of adsorption and mechanical properties of monolayer films at the air-water interface involved in the formation and the stability of foams respectively. The TPP extracted from skimmed milk showed the lowest values as well as a significant reduction in surface tension and presented a good mechanically resistant film. The TPP extracted from WPC presented a better foaming capacity and stability which was unexpected. However, foaming properties and surface properties of TPP fractions depended on the pH. The considerable influence of extraction source and method on proteose-peptone's properties were highlighted.