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Effect of compositional formulation on texture and microstructural of whey protein foam

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ABSTRACT

This research was designed to determine whether different formulations of proteinaceous foams would help to retain a higher content of olive oil. The amount of olive oil absorbed, retained and released by these foams was calculated and texture tests were performed. X-ray microtomographical (μCT) analysis was also used to study the structure of the foams quantified by image analysis. Furthermore, the information gained from the μCT analysis i.e. the geometric parameters mentioned above, provided the required information to characterise and to investigate if any, the correlation among the microstructures and textural properties of the proteinaceous foam samples. The results from this study do not only prove that the percentage of absorbed, retained and released olive oil of this protein foams is highly affected by their formulation but also showed that a correlation exists among some of the microstructural and mechanical parameters of the proteinaceous foams.

1. Introduction

Whey protein isolate (WPI) consists of five major components including β-lactoglobulin, α-lactalbumin, bovine serum albumin, immunoglobulin, and proteose peptones (Langton & Hermansson, 1992; Schmidt & Morris, 1984) which contain a few proline amino acids and numerous disulphide bonds (Kurt & Zorba, 2005; Smith, 1988). It is widely used in the food industry in regard to its binding (Kontopidis, Holt, & Sawyer, 2002, 2004), emulsifying (Leman, Dolgan, Smoczynski, & Dziuba, 2005), foaming (Bals & Kulozik, 2003), and gelling (Kerstens, Murray, & Dickinson, 2005) properties. As ingredients in food, whey proteins are used also for their high nutritive value, reasonable cost and GRAS status (Andrès, Zaritzky, & Califano, 2006; Hsu & Sun, 2006).

Generally, the functional properties of food proteins may be classified into three main groups: (a) hydration properties, dependent upon protein–water interactions which have an important bearing on wettability, swelling, adhesion, dispersibility, solubility, viscosity, water absorption and water holding; (b) interfacial properties including surface tension, emulsification and foaming characteristics; and (c) aggregation and gelation properties, which are related to protein–protein interactions (Kresic, Lelas, Herceg, & Rezerk, 2006).

Whey protein products are well known as replacements for egg proteins in confectionery (Muschiolik & Draeger, 1993) and bakery products (Duxbury, 1993; Morr, Hoffmann, & Buchheim, 2003); they are also used as functional ingredients, as milk replacers in dairy products such as ice cream (Vulink, 1995) and as common non-meat additives used by the meat industry.

Whey proteins have been used in food in the form of powder, solution, self-supporting cold set gel (U.S. Patent 5, 1993) and foam. In the former three cases whey proteins are used to improve emulsification, water binding and texture (Holland, 1984; Shie, 2004), in the latter case to carry vegetable oil (Del Nobile et al., 2009; Mastromatteo, Incoronato, Conte, & Del Nobile, 2011). The strategy proposed by Del Nobile et al. (2009) to carry olive oil in salami seems to be of great interest. The authors used whey protein-based foam obtained by mixing whey protein, NaCl, Na_2CO_3 and water; after this mixture was cooked, minced, soaked with olive oil and added to meat mix.

Because of the potential use of whey protein foam for meat preparation or food, in general and the increasing demand for low-fat diets, i.e. products to contain less animal fat, we determined whether different formulations of proteinaceous foams would help to retain higher content of olive oil. In particular, the amount of olive oil absorbed, retained and released was calculated and compression tests were performed to simulate the working of meat mixture. Furthermore, X-ray microtomographic analysis, a non-invasive technique that has several advantages over other methods, including the ability to image low moisture materials, was used to study the microstructure of the protein foams to understand how the physical structure of the foam affects the amount of olive oil absorbed.

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2. Materials and methods

2.1. Proteinaceous foam formulation

In this research two types of whey protein (WP) are used: WPI 895 (Farmalabor, Canosa di Puglia, Italy) and Provon 290 (Glanbia, Faravelli, Milan, Italy), from now onward named as A and B, respectively.

According to Del Nobile et al. (2009), whey protein-based foam was obtained by mixing whey protein, NaCl, Na_2CO_3 and distilled water (the quantities are indicated in Table 1). This mixture was whipped at the high-speed setting for about 3 min in the blender (Moulinex, France); successively it was cooked at 160 °C for 40–50 min in the oven (Moulinex Activys, France). The other proteinaceous foams were obtained by mixing the ingredient listed in Table 1 and the mixtures were cooked as above. Set the amount of NaCl and Na_2CO_3, the amount of other ingredients was determined on the basis of previous tests in which olive oil absorbed percentage of formulated foams was calculated. The highest percentage value has determined the amount of ingredient to be used per formulation.

2.2. Oil absorption capacity

All foams were uniformly sliced to a thickness of 15 mm and the crust was removed allowing only crumb texture measurements. Cylindrical crumb samples (28 mm diameter) were cut from the centre of each foam slice using a circular cutter. Oil absorption capacity was measured on six crumbs per formulation. Each crumb sample of known weight was immersed in plastic tray containing olive oil for 48 h, then it was placed on a filter for 24 h and its weight was noted. A technical balance (Gibertini Europe, Milan, Italy) with an accuracy of ±0.1 g was used.

Absorbed oil value represents the amount of oil absorbed by the foam per 100 g of sample and was calculated as:

$$\text{Absorbed}\% = \frac{\text{absorbed crumb weight} - \text{dry crumb weight}}{\text{dry crumb weight}} * 100.$$

Table 1
Composition and amount by weight of each constituent in foam samples.

Sample	Ingredient	Quantity (g)
WP	Whey protein	100
	NaCl	4
	Na_2CO_3	10
	Water	120
WP + GluA	Whey protein	50
	Gluten Sigma-Aldrich	50
	NaCl	4
	Na_2CO_3	10
	Water	80
WP + GluB	Whey protein	50
	Gluten Molino Agostini	50
	NaCl	4
	Na_2CO_3	10
	Water	100
WP + SP	Whey protein	70
	Starch potato	30
	NaCl	4
	Na_2CO_3	10
	Water	100
WP + S	Whey protein	80
	Soy protein	20
	NaCl	4
	Na_2CO_3	10
	Water	120
WP + O	Whey protein	100
	Olive oil	20
	NaCl	4
	Na_2CO_3	10
	Water	100

The retained oil in percent was determined as follows:

$$\text{Retained}\% = \frac{\text{absorbed compressed crumb weight} - \text{dry crumb weight}}{\text{dry crumb weight}} * 100$$

and denotes the amount of oil retained in the compressed crumb per 100 g of sample.

Finally percentage released oil was estimated according to the following expression:

$$\text{Released}\% = \frac{\text{absorbed crumb weight} - \text{absorbed compressed crumb weight}}{\text{absorbed compressed crumb weight}} * 100$$

and is the amount of oil released from crumb after compression per 100 g of sample.

2.3. Crumb texture analysis

Soaked foam sample firmness was determined instrumentally by means of compression test using a Texture Analyzer (Zwick/Roell model Z010, Genova, Italy). An insert plate fixed in the universal work platform (100 × 90 × 9 mm) and compression die (75 mm diameter) were the parallel plates inside which the cylindrical foam crumb samples were placed. The force required to compress circular crumb to a predetermined level of penetration against a rigid back plate using a cylindrical plunger was recorded for each sample tested. Pre-load of 0.3 N, load cell of 1 kN, maximum percentage deformation of 50% and a constant crosshead speed of 100 mm/min were the experimental conditions. Textural parameters evaluated included the elastic modulus (E_{mod}), the force required for compression of the foam sample by 50% ($F_{50\%}$) and the area under the force–deformation curve ($W_{50\%}$).

2.4. Tomographic analysis

For X-ray microtomographical analysis (μCT) the proteinaceous foam samples were imaged under the same conditions, using the Skyscan 1172 high-resolution desktop X-ray microtomography system (Skyscan, Belgium). The foam samples were prepared as those used for the texture analysis and were placed on a round plate; the source and the detector were fixed, while the sample was rotated during measurement. Power settings of 100 kVp and 100 μA were used. A CCD camera with 2000 × 1048 pixels was used to record the transmission of the conical X-ray beam through all samples. The distance source–object–camera was adjusted to produce images with a pixel size of 17.13 μm. Four-frame averaging, a rotation step of 0.40° and an exposure time of 1767 ms were chosen to minimise the noise, covering a view of 180°. Scan time, on average, required 30 min. A set of flat cross section images was obtained for each sample after tomographical reconstruction by the reconstruction software NRecon (Skyscan). For image processing and analysis the Skyscan software, CT-Analyser (CTAn) was used. For data analysis, prior to 3D reconstruction, a component-labelling algorithm, available within CTAn, was used to isolate the largest 3D connected structures. The following five tomographical geometric parameters were measured using the CTAn software (Skyscan): Percent object volume (POV), Object surface/volume ratio (OSVR), Fragmentation index (FI), Structure thickness (St.Th) and Structure separation (St.Sp). Where, i) Percentage object volume is the proportion of the VOI (volume of interest) i.e. pores; ii) Object surface/volume ratio is the basic parameter in characterising the complexity of the structures and is also the basis of model-dependent estimates of thickness i.e. size and distribution of the pores present in each sample; iii) Fragmentation index is an index of connectivity of the structures, which was developed and defined by Hahn and Delling (1992), iv) Structure thickness calculates or estimates the average structure diameter of the object from