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Physico-chemical and sensory characteristics of freeze-dried and air-dehydrated yogurt foam

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ABSTRACT

Foaming followed by drying is a potential methodology for production of crispy snacks, especially at a restaurant or catering level. The influence of either freeze-drying or air-drying on the physicochemical (weight loss, moisture content, water activity, instrumental colour, instrumental texture), structural (Scanning Electron Microscopy –SEM-) and sensory features of whipped yogurt foam was studied. Air-dried (AD) yogurt foams showed significantly higher water activity values than freeze-dried (FD) ones. In the instrumental texture analysis, FD foams had a significant lower maximum force (hardness) and total number of fracture events than AD ones. For instrumental colour, FD foams showed higher values for lightness and lower for yellowness and browning index. SEM images evidenced that FD foams kept the foamed structure, while the structure of AD ones was totally collapsed. Sensory results indicated a higher degree of hardness and crispness in AD foams than in FD ones. Using different drying technologies, dried foams can be tuned to show completely different features.

1. Introduction

Crispy and crunchy textures are desirable quality features and contribute to the enjoyment of foods (Elder & Mohr, 2016). This is one of the reasons behind the enormous success of crispy snacks worldwide. There is a growing global trend for producing low fat and low calorie crispy snacks; such a trend has been mainly focused on plant snacks (Tzia, Giannou, & Varzakas, 2015, pp. 573–583). In parallel, self-production of customized culinary snacks at restaurants and catering is also a worldwide trend (Myhrvold, Young, & Bilet, 2011). These crispy products are not anymore only a part of the appetizers, but they also constitute an important part of main dishes and desserts.

Dry crispy foods consist of cells or cavities, usually filled with air, and a structural phase or cell walls, that are formed by a brittle matrix (Djaeni, Prasetyaningrum, Sasongko, Widayat, & Hii, 2015). The combination of foaming and subsequent drying is a straightforward procedure for producing crispy snacks. Different technologies can be used for this purpose, freeze-drying and air-drying being two of the most well-known ones. Each drying technique has its own advantages and limitations, leading to snacks showing different flavours, textures, and colours. Moreover, the combined use of appropriate hydrocolloids has been shown to improve the textural features of crispy snacks. Indeed, dehydration of a number of different types of foams containing selected hydrocolloids has been used by many chefs to produce snacks (Myhrvold et al., 2011). Air drying is a traditional processing that involves simultaneous interface transfer of heat and mass: the food is placed in a closed environment in which hot air circulates, leading to the evaporation of water from the product (Fellows, 2009, pp. 481–524). It is relatively low in cost and easy to operate. However, air-drying usually implies high temperature and long drying time, which in turn leads to physical and chemical changes, such as loss of structure, shrinkage, Maillard reactions or lipid oxidation. These may cause serious lowering of the nutritive and sensory features (Rahman, 2001). At the same time, the intense water lost and the subsequent increase in solids content may lead to the formation of a solid and brittle structure, that due to its cellular rupture, contributes to a crispness sensation, which is crucial in crispy snacks (Aguilera & Baffico, 1997; Salvador, Varela, Sanz, & Fiszman, 2009).

In freeze-drying, water is removed by sublimation from frozen materials under conditions of low pressure and temperature (Khalloufi & Ratti, 2003). A prominent factor in freeze-drying is the

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structural rigidity afforded by the frozen substance at the surface where sublimation occurs. This rigidity, to a large extent, prevents collapsing of the solid matrix remaining after drying. The result is a porous non-shrunken structure in the freeze-dried product (Bruttini & Liapis, 2006). Thus, the main characteristics of FD products are low bulk density, high porosity, fresh taste and aroma retention as compared to products obtained using air-drying (Rahman, 2001). Nevertheless, operation costs are high and processing time is usually much longer than for conventional air-drying.

Both types of drying operations have been suggested as potential tools for producing customized snacks, but there is a lack of knowledge about the consequences on the quality of the elaborated product. Thus the aim of this study was to address the effect of these two different drying methodologies (freeze-drying and air-drying) upon the physical, sensory and structural features of dehydrated yogurt foams.

2. Material and methods

2.1. Production of yogurt snacks

Dried yogurt snacks were prepared using the recipe described by (Kamozawa & Talbot, 2007) with some modifications. The formula for 100 g of product is as follows: 42 g of plain yogurt (Mercadona, Spain) was mixed with 25 g of mineral water. Separately, other 25 g of water were brought to a simmer and 4.4 g of isomaltose, 2.2 g of maltodextrin (both from Cargill Iberica, Spain) and 0.2 g of sodium chloride were added until totally dissolved. 1.0 g of methylcellulose (Metolose MCE-400, Shin Etsu Chemical, Japan) and 0.2 g of xanthan gum (El Mazuelo, Spain) were then added and stirred. Immediately after, the mixture was added to the yogurt mix, mixed and put in a 1 L stainless steel foaming siphon, charged with one N_2O cartridge, shacked vigorously and immediately put in a water/ice bath for 90 min. The siphon containing the mixture was kept under refrigeration (aprox. 4 °C) for 4 days. After this resting period, the mixture (aprox 10 g) was whipped onto cupcake silicon moulds. Half the produced whipped yogurt foams were frozen down to −80 °C for 24 h, and were subsequently and immediately freeze-dried (FD) in a lab freeze-dryer (Lyoquest, Telstar, Spain) at 0.1 mbar for 22 h. The rest of the foams were directly dried in a domestic dehydrator (Excalibur, Sacramento, USA), at 57 °C for 24 h. After dehydration, all samples were kept into plastic sealed boxes with silica gel inside until analysis. These two different processing procedures were replicated 5 times.

2.2. Analytical determinations

Weight loss was calculated by difference of weight before and after processing. Moisture content was determined by drying the samples (aprox 1 g) at 102 °C (AOAC, 2000). Water activity was measured using a LabMaster a_w meter (Novasina, Switzerland), that was calibrated using a set of salt solutions. Samples were analysed in duplicate for each of these measurements.

2.3. Instrumental colour

Colour measurements were made on each of selected freeze-dried or dried foam samples. The Comission Internationale d'Eclairage (CIE) L*, a* and b* values were determined using a portable spectrophotometer (Konica Minolta CM-600d, Osaka, Japan) that was calibrated with a standard white calibration tile. Fifteen replicates were performed for each FD or AD foam samples. L*, a* and b* values were used to calculate chroma (C) and hue angle (h°) by the following equations:

$$\text{Chroma(C)} = \left(a*^2 + b*^2\right)^{1/2}$$

$$\text{Hue angle}(h^\circ) = \text{arctg}\ \left(b*/a*\right) \times \left(360^\circ/2 \times 3.14\right)$$

Browning index (BI) was calculated according to (Roldan et al., 2015)

$$(BI) = [100(x - 0.31)]/0.17$$

where $x = (a^* + 1.75L^*)/(5.645L^* + a^* - 0.3012b^*)$.

2.4. Scanning electron microscopy (SEM)

Microstructure of FD and AD foams was examined with a scanning electron detector microscope FEI QUANTA 3D FEG (FEI Company, Hillsboro, EE.UU.) in high vacuum conditions mode using EDT (Everhart Thornley Detector). Samples were sectioned with a single-edged razor blade and mounted on aluminium stubs with a double-sided coated carbon conductive adhesive sheet. Then, they were subjected to metallization (sputtering) with a thin layer of a conductive gold coating for 8 s in order to amplify the secondary electron signal. After metallization, the samples were imaged operating at 10 kV with focused electron beam of Ga + (current of $<6e^{-4}$ Pa) and observed with magnifications comprised between 65 and 750 times.

2.5. Instrumental texture

A TA-HD*i* Texture Analyser (Stable Micro Systems, Godalming, UK) was used for the compression tests with a 25 kg load cell. The probe used was the 5 blade Kramer Shear Cell (HDP/KS5) at the following settings: test speed 2 mm/s and trigger force 0.04 N. Each type of sample was placed into the Kramer cell so that the total height was the same (4 cm), and was crushed from the top. Fifteen replications were performed for each kind of samples. The following parameters were calculated from the force *versus* time curves: maximum force (N), respective work load (Ns), number of peaks of the curve or fracture events (drop in force higher than 0.049N), and displacement (mm), which means the length of the curve from the first breakdown event until maximum force.

2.6. Sensory analysis

A panel of 15 assessors with experience in sensory descriptive evaluation was used to evaluate the two different types of foams (FD and AD). Panellists were previously trained during 3 months, first in group sessions in order to define descriptors for products with similar characteristics (puffed snacks) and to reach a consensus among panellists on the meaning of every attribute. Subsequently, they continued their training in six individual sessions with different puffed snacks with the aim of training them to recognize specific texture descriptors (hardness, crispness, crunchiness and crumbliness) (Roudaut, Dacremont, Pamies, Colas, & Le Meste, 2002) and taste descriptors (Bruwer, MacGregor, & Bourg, 2007; Heenan, Dufour, Hamid, Harvey, & Delahunty, 2009). The selected sensory attributes analysed and their descriptions are shown in Table 1.

Testing was carried out in a sensory laboratory equipped with individual booths (ISO, 2012). The intensities of sensory attributes were scored on 9 cm unstructured line scales labelled from "low" (0) to "high" (9). Samples were served in random order (one of each type in each session), each one on a separate glass tray,