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Effect of micro-gel shape and concentration on sensory perception of micro-gels-enriched stirred yoghurts

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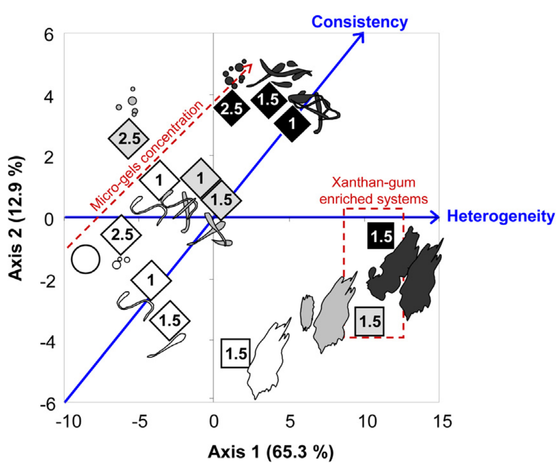
HIGHLIGHTS

- Experimental design has been established in order to create new stirred yoghurts textures.
- Effect of micro-gel size, shape and concentration on stirred yoghurt texture was studied.
- Sensory analysis and instrumental measurements were combined.
- Textural properties are dissociated by consistency and graininess.
- Sensory analysis was more accurate than instrumental analysis to distinct and to classify products.

GRAPHICAL ABSTRACT



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ABSTRACT

Protein-enriched micro-gels of different morphologies were incorporated into stirred yoghurts. Resulting sensory and rheological properties were investigated. An experimental design was defined with two factors (micro-gel shape and concentration). Four different shapes were designed and three micro-gel concentrations were used (2.5, 5, 10 wt%). A Flash profile with experienced assessors was performed in combination with instrumental measurements in an attempt to relate the added micro-gel shape and concentration to sensory perception. The most important attributes to explain the texture of the micro-gels-enriched stirred yoghurts were consistency and graininess, which could then be associated to structural parameters. It has been shown that an increase in particle lengths and widths gave rise to a visual or mouthfeel grainy perception whereas the presence of entangled micro-gels contributed to instrumental and sensory consistency. Therefore, the sensory properties of micro-gels-enriched stirred yoghurts could clearly be distinguished depending on the characteristics of the added particles.

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1. Introduction

Stirred yoghurts are widely consumed products. They are generally formulated by acidification of milk with bacterial cultures and then disrupted by stirring and sieving to give a smooth semi-liquid product [1,2]. From a physical point of view, stirred yoghurts can be considered as a highly concentrated dispersion of gel particles in a serum phase [3].

Many food systems contain particles of various sizes, such as starch granules [4,5], insoluble fibres [6,7] or protein aggregates as in the case of stirred yoghurts [8,9]. However, exceeding a given particle size, textural defects of stirred yoghurts such as graininess are sometimes observed and can affect consumers sensory appreciation [2,10]. The degree of graininess perceived in the mouth is influenced by particle size and type (hardness and shape) [11–13] but also by particle concentration and the dispersion medium [14].

Structure of food and its chemical physics characteristics have a significant effect in the mouth and thus, on the sensory perception [15]. Previous microstructural and sensory studies have shown the importance of the structural parameters (particle size, solids content and serum rheology) for the sensory perception of semi-liquid products such as apple puree [16]. Moreover, it has been shown that increased hardness of particles could greatly affect gritty sensations and thus the graininess threshold value [11]. Therefore, understanding the relationship between microstructure and sensory properties is important in order to produce products with the desired properties.

Most studies on the "perception of particles" have investigated the difference in particle size but few of them have focused on particle shape [11]. Indeed, formulating a wide range of particle sizes and shapes with defined properties is not an easy task. Using a mixture of gelatin and polysaccharide, previous studies have established that under specific conditions of applied shear and controlled polymer gelation, it was possible to trap the dispersed phase in anisotropic morphologies [17–19]. It has been recently shown that controlling phase separation and protein gelation in polysaccharide-enriched acid milk gel systems allow designing specific micro-gels varying from filamentous to spherical morphologies [20].

Characterization of the textural properties of a food product can be achieved by examination of its rheological behaviour and its microstructure, so long as the instrumental information can be related to the perception of texture by consumers [21]. Even if several studies have been conducted to investigate the relationship between sensory analysis, rheological measurements and microstructure [21–24], only few of them examined systematically the correlation between instrumental measurements and texture perception using a controlled experimental design [25–27].

The objective of the current study was to investigate the effect of several types of micro-gels differing from sizes, shapes and concentration incorporated in a standardized dispersion medium, upon the rheological and sensory characteristics of the final products. For this purpose, specific protein-enriched micro-gel morphologies (from filamentous to spherical) and size (from 20 to 200 μm long) were designed. An experimental design, composed of four different shapes and a 3-level micro-gel concentration, was used in order to create a wide range of textures of stirred yoghurts. Flash profile was performed with experienced assessors to evaluate the relative positioning of the products and collect specific attributes of the resulting texture.

2. Materials and methods

2.1. Preparation of the micro-gels-enriched stirred yoghurts

Dispersion medium of the micro-gels consisted of commercial fat-free stirred yoghurt purchased from supermarkets (manufacturer: Cora, France). Yoghurts contained 5.5% of carbohydrates, 5.5% of milk protein and no fat. Care was taken not to use stirred yoghurt including fat to avoid the influence of fat globules on sensory perception. The commercial yoghurt contained skimmed milk, lactose, milk proteins and bacterial cultures and no hydrocolloid that could affect structural properties or interact with added micro-gels. Yoghurts contained slightly higher protein content than conventional yoghurts as it is mostly applied for industrial low-fat yoghurts in order to avoid syneresis.

Four types of micro-gels were manufactured using the combined process of phase separation and acid-induced milk protein gelation as described in previous papers [20,28]. Due to biopolymer incompatibility, adding specific amount of polysaccharides to skim milk created emulsion-like microstructures, which could then be trapped through gelation at a chosen state. From guar gum or xanthan gum-enriched milk systems, a wide range of micro-gel morphologies from very long protein-enriched filaments around 200 μm to spherical micro-gels of 20 μm, was designed (Fig. 1). Protein content of the micro-gels was 200 g kg^{-1} (values obtained using Kjeldahl method).

Micro-gels-enriched stirred yoghurts were prepared in the laboratory by manufacturing guar gum or xanthan gum/acid milk gels followed by a separation-reconstitution procedure. Skim milk with 46 g kg^{-1} protein was reconstituted by dispersing low-heat skim milk powder (CH low heat, Ingredia, Arras, France) in Milli-Q water under continuous stirring for 1 h at room temperature and kept overnight in a refrigerator in order to let proteins fully hydrate. The milk was then heat-treated at 80 °C during 7 min and cooled down to 60 °C for dry powdered guar gum (Viscogum MP, Cargill, USA) or xanthan gum (Satiaxane, Cargill, USA) addition. The mixture was stirred 30 min at 60 °C and finally cooled down to 43 °C. Mixed solutions were prepared at a guar gum concentration of 0.3 wt% and at a xanthan gum concentration of 0.05 wt%.

Guar gum/milk mixture was acidified by addition of different levels (1, 1.5 or 2.5 wt%) of glucono-δ-lactone (GDL) (Sigma Chemical Co., St. Louis, MO, USA) whereas a fixed GDL concentration of 1.5 wt% was used to acidify xanthan gum/milk mixture. The mixtures were then incubated at 43 °C until a pH of 4.60 (±0.05) for 1.5 and 2.5 wt% GDL and pH of 4.7 (±0.05) for 1 wt% GDL, respectively, was obtained. Changing GDL concentration, i.e. gelation rate, modified the delay in time for the system to begin phase separation before kinetical trapping through protein gelation. Therefore, small spherically shaped protein-enriched micro-gels were found in the system acidified with 2.5 wt% GDL, while filamentous structures appeared in the mixed gels acidified with 1 wt% GDL, i.e. with the lowest gelation rate (Fig. 1).

After cooling down to 20 °C during 1 h at room temperature, the gels were mechanically sheared by passing through two successive plastic pipes (length: 40 cm and internal diameter: 7 mm; length: 100 cm and internal diameter: 3 mm) while pushed by a Masterflex® peristaltic pump (Cole Parmer, Vernon Hills, USA) at 380 mL min^{-1}. It is worth noting that the filamentous and spherical shapes of micro-gels made from the guar gum-enriched system existed before stirring the acid gels that were not oriented after stirring. On the contrary, micro-gels made from the xanthan gum-enriched systems originated from the disruption of the gel by the stirring process, which gave rise to rough micro-gels surface.

The protein-enriched micro-gels were separated from the supernatant of the guar gum or xanthan gum stirred acid milk gels by centrifugation at 5000 × g for 15 min at 20 °C in a 3.18 K centrifuge (Sigma GmbH, Germany). Subsequently, micro-gels were incorporated in the commercial stirred yoghurt by mixing gently manually thoroughly for 1 min using a metal spoon. All samples were stirred by a unique person in order to maximize mixing repeatability. Homogeneity of the products was carefully checked just after mixing and before instrumental and sensory