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Impact of native and chemically modified starches addition as fat replacers in the viscoelasticity of reduced-fat stirred yogurt

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ABSTRACT

Three reduced-fat stirred yogurts were prepared from reconstituted milk (12.5 g L^{-1} of milk-fat) added with native maize (Y_{NMS}), and chemically modified maize (Y_{MS}) or tapioca (Y_{TS}) starches (10 g L^{-1}). The chemical composition, syneresis, flow and viscoelastic properties of the reduced-fat yogurts were evaluated and compared with those of a full-fat control yogurt (Y_C; 25 g L^{-1} of milk-fat) without starch. The rheological analysis showed that the Y_C exhibited lower apparent viscosity-shear rate profiles and dynamic viscoelastic moduli, but higher syneresis than the reduced-fat yogurts. The reduced-fat yogurts showed little variation in their flow and viscoelastic properties with storage time (15 days). The addition of native or chemically modified starches from different origin to reduced-fat yogurts contributed to the formation of more stable dispersed acidified milk gelled systems.

1. Introduction

Per capita consumption of yogurt has doubled in the new millennium, while overall per capita dairy consumption stayed the same during the same period. Annual yogurt sales have grown 113% by weight since 2001 (USDA, 2013). The increase in yogurt consumption has been associated to a shift in the preference for Greek yogurt, an extra-thick, protein-rich yogurt, than the traditional yogurts marketed. Greek yogurt now accounts for 36% of the $6.5 billion in total US yogurt sales (Gruley, 2013). Nevertheless, the awareness of the link between diet and health is still a major factor influencing consumers' preferences, so that reduced-fat or non-fat yogurts remain popular due to their nutritional and potentially therapeutic characteristics (Noronha et al., 2008). Yogurt is a composite gel in which denatured serum proteins act as fillers or binders within a casein matrix and milk-fat globules are incorporated into the final structure (Xiong et al., 1991). The particular composition and the spatial arrangement of the components are responsible for the pleasant sensation from eating it, with firmness and creaminess being some of the sensory attributes perceived by consumers (Cayot et al., 2008). However, the structural and mechanical characteristics of yogurt can be altered by reducing its fat content, resulting in poor sensory and texture characteristics and high syneresis (Sandoval-Castilla et al., 2004).

An interesting simple alternative for formulating reduced-fat yogurts is to create physical building blocks (structural elements) within the continuous phase that may substitute the functionality of the removed milk-fat. The use of native and modified starches as fillers in low-fat food formulations has been suggested for a long time (Belmont et al., 1991). The relatively recent recognition of incomplete digestion and absorption of starch in the small intestine as a normal phenomenon has rated interest in non-digestible starch fractions (Englyst et al., 1992). In particular, chemically modified starches, that also qualify as resistant starches (RS), have an important role in human health, and withstand gelatinization (granule swelling) under most heating regimes have been recently targeted for use in food products (Fuentes-Zaragoza et al., 2011). Apart from the potential health benefits of RS, it impacts minimally the sensory properties of food compared with traditional sources of fibre such as whole grains, fruits or bran. Among the desirable physicochemical properties of starches are their viscosity, gel formation ability and water-binding capacity which make them useful in a variety of foods. There is scant information regarding the application of RS in dairy products, being limited to its inclusion in imitation cheese (Duggan et al., 2008; Noronha et al., 2008).

The objectives of this work were: (1) to evaluate the rotational and oscillatory shear rheological properties, chemical composition,

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and syneresis of reduced-fat yogurts, in which milk-fat was partially replaced by native maize, chemically modified maize and tapioca commercial starches; and (2) to compare the rheological properties and syneresis results with those displayed by a full-fat control yogurt.

2. Materials and methods

2.1. Materials

The starches used as milk-fat replacers were: (a) a chemically modified food starch refined from tapioca (TS) (National Frigex, crosslinked, EU Classification 1442); (b) a chemically modified food starch refined from waxy maize (MS) (Thermflo, crosslinked, EU Classification 1442); and (c) a native food maize starch (NMS). The first two samples were obtained from Ingredion Mexico, Guadalajara, State of Jalisco, Mexico, and the latter from Gluten y Almidones Industriales, Mexico City, Mexico. Manufacturer did not provide information regarding the degree of substitution or the type of chemical modification to which starches were subjected. However, reports in the open literature mentioned the range 0.055–0.148 for normal maize and 0.033–0.400 for tapioca starches (Miller et al., 1991). Whole milk powder (NIDO®, Nestle, S.A. de C.V. Mexico), skim milk powder (Lactomix®, DILAC, S.A. de C.V. Mexico) and freeze-dried lactic culture (*Streptococcus thermophilus*, *Lactobacillus bulgaricus* and *Lactobacillus lactis* (CHOOZIT MY 800, Danisco France, SAS, Dangé Saint Romain, France), were used to prepare the yogurt variations.

2.2. Stirred yogurt variations and manufacture process

A full-fat control yogurt (Y_C) without starch was manufactured from reconstituted milk containing 25.0 ± 0.1 g L^{-1} of milk-fat and 120 ± 1 g L^{-1}of total milk solids. Three reduced-fat yogurts containing 10 g L^{-1} of TS, MS or NMS were made from reconstituted milk containing 12.5 ± 0.1 g L^{-1} of milk-fat and 120 ± 1 g L^{-1} of total milk solids, and were coded as: Y_{TS}, Y_{MS}, and Y_{NMS}. It has been reported that addition of low levels of starch (up to 1%) on the properties of acid gels is additive, but higher levels (1.5–2.0%) non-additive, even producing a diminished effect on the storage modulus (Oh et al., 2007). Ten-litre batches of each one of the stirred yogurt variations were prepared in triplicate using a completely randomized experimental design. Whole and skim milk powders were blended to obtain the milk-fat content desired and were reconstituted at 35 ± 1 °C with gentle agitation. At this point TS, MS or NMS were added to the reconstituted milk batches by moderate mixing at 4000 rpm during 5 min using an Ultra-Turrax T-50 basic homogenizer (IKA Works, Inc., Wilmington, DE, USA). The milk batches were refrigerated at 4 °C for 24 h, to allow full hydration of the powders, before usage. Afterwards the reconstituted milk batches were heated to 40 ± 1 °C, added with 60 g L^{-1} of sugar, pasteurized (85 ± 1 °C, 15 min), cooled (45 ± 1 °C) and inoculated with 0.03 g L^{-1} of the freeze-dried starter culture (Sandoval-Castilla et al., 2004). The milk batches fermentation process was carried out at 45 ± 1 °C until an acidity of 80–85 °D was reached. The fermented milk batches were cooled and stored at 4 ± 1 °C during 24 h, and then the gels obtained were removed from refrigeration and were gently stirred with help of a mechanical mixer (Caframo, RZR1, Cole-Parmer, Vernon Hills, Il, USA) at 500 rpm during 1 min (Ramírez-Santiago et al., 2010). The stirred yogurt variations were stored at 4 ± 1 °C until required for chemical composition analysis, syneresis quantification and rheological evaluation. All the yogurt variations were prepared by triplicate using a completely randomized experimental design.

2.3. Chemical composition

After 5 days of preparation, the yogurt variations were analyzed for protein by the Kjeldahl method, fat by the Gerber method, and moisture by oven drying (AOAC, 1995). All analyses were carried out by triplicate.

2.4. Syneresis

Syneresis determination was done using the method proposed by Keogh and ÓKennedy (1998) at 1 and 15 days of storage. 14 g of stirred yogurt (4 ± 1 °C) were placed in tubes and centrifuged at 222*g* for 10 min, at 4 ± 1 °C. The clear supernatant was poured off, weighed and expressed as percent weight relative to original weight of yogurt. Syneresis analyses were carried out by triplicate.

2.5. Rheological properties of the stirred yogurts

Dynamic oscillatory measurements of the yogurt variations were carried out using a Physica MCR 301 rheometer (Anton Paar, Messtechnik, Stuttgart, Germany), with a cone-plate geometry, in which the rotating cone was 50 mm in diameter, and cone angle of 1° with a gap of 0.05 mm. About 3.8 mL of sample was carefully placed in the measuring system, and left to rest for 10 min at 4 °C for structure recovery. Amplitude sweeps were carried out at 4 °C to characterize the viscoelastic linear region of the yogurt variations by applying a strain sweep ranging from 0.001% to 100% at 1 Hz. Frequency sweeps were carried out in the range of 0.01 to 10 Hz in the linear regime (0.1% strain) at 4 °C. Temperature maintenance was achieved with Physica TEK 150P temperature control and measuring system. The storage modulus (G'), the loss modulus (G'') and the loss angle ($\tan\delta = G''/G'$) were obtained from the equipment software (RheoPlus/32 V2.62) in all cases. Flow curves of the yogurt variations were obtained at 4 °C by varying the shear rate from 0.003 to 300 s^{-1}. Analysis was performed by triplicate on each of the yogurt variations at 1 and 15 days of storage.

2.6. Data analysis

Simple classification variance analysis was applied and whenever it was adequate Tukey's test was used in order to determine differences between the composition and syneresis data of the yogurt variations. The significance was established at $p \leqslant 0.05$. Data analysis was done using Statgraphics Plus software (Statistical Graphics Corp., Manugistics, Inc., Cambridge, MA).

3. Results and discussion

3.1. Chemical composition

The average composition in wet basis of the yogurt variations is given in Table 1. The protein and fat contents in all variations ranged between 3.2 and 3.6 g per 100 g, and 1.2 and 2.4 g per 100 g, respectively. All the yogurt variations had similar moisture content (∼83%), but Y_C had significantly higher protein and fat content than Y_{TS}, Y_{MS}, and Y_{NMS}. The lower protein and fat contents in the reduced-fat yogurts can be attributed to the reduction of milk-fat content and its replacement by the different starches. Acidity of the yogurt variations aged 1 day was comparable, ranging from 84.3 to 85.7 °D (Table 1). However, after 15 days of storage the acidity of all the yogurt variations increased significantly (106.7 to 111.3 °D), with the yogurt variations incorporating maize starches (Y_{MS} and Y_{NMS}) presenting significantly higher acidity than the tapioca starch yogurt variation and Y_C. In normal yogurt, acidity arises as a consequence of lactic acidification obtained at