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Effect of sucrose, stevia and xylitol on rheological properties of gels from blends of chestnut and rice flours

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ABSTRACT

The development of high quality gluten-free products requires the understanding of the phenomena that dictate the ingredient interactions commonly used in foodstuff. In this work, the main objective was to develop alternative gluten-free gelled desserts from blends of chestnut flour (Cf) and whole (Rw), Agulha (Ra) or Carolino (Rc) rice flours. The impact of sucrose, stevia and xylitol on textural, rheological and structural properties of selected gels was investigated. Texture results indicated that studied gels in the presence of sucrose and xylitol decreased significantly the firmness. Rheological outcomes showed that the temperature ramps on heating of Cf/Rw gels were similar to those obtained for Cf/Ra, whereas Cf/Rc gels presented a particular pattern. The presence of sucrose resulted in a significant decrease in the values of storage and loss moduli. Confocal microscopic images showed that the sugar addition leads to a less aggregated structure with fracture lines well marked.

1. Introduction

In the last decades, gluten-free diets are gathering new followers and subsequent gel research focuses more strongly on new mixtures as a result of industrial demands for new products with higher quality (Moreira, Chenlo, Torres, & Glazer, 2012; Moroni, Bello, & Arendt, 2009). In the most of the available products on the market, low technological and nutritional quality is observed (Mariotti, Lucisano, Pagani, & Ng, 2009). A few studies indicated that the blending of chestnut flour (Cf) with rice flours (Rf) can be an interesting approach to produce gluten-free products (Demirkesen, Mert, Sumnu, & Sahin, 2010; Sacchetti, Pinnavaia, Guidolin, & Dalla Rosa, 2004). In a recent work (Torres, Fradinho, Raymundo, & Sousa, 2013), it was demonstrated that the gelation ability of a mixture of Cf and different types of Rf could be used as an interesting alternative to commercial gluten-free desserts, with subsequent multiple advantages from the economic and health hazard points of view. The development of these products requires the understanding of the phenomena that dictate the ingredient interactions commonly used in food formulations. Sugars are usually used in food gels as sweetening agents and affect notably the gel structure and texture (Bayarri, Durán, & Costell, 2004). Sucrose is probably one of the most studied sweeteners, since it plays an important role as an ingredient or preserving agent in many formulations and technological processes (Moreira, Chenlo, & Torres, 2011). Usually sugar provides good structures, flavour and texture to the product, contributes to moisture retention and prolongs freshness (Nip, 2007).

In some diets the energetic value of sucrose is considered an undesirable feature, leading to growing interest in low-calorie alternatives to sucrose (Bayarri, Izquierdo, & Costell, 2007). Attempts to provide sweetness for the diet have included several synthetic sweeteners which are often regarded either as having an undesirable aftertaste or as being linked to health concerns (Holm, Wendin, & Hermansson, 2009). Recent publications (Guggisberg, Piccinali, & Schreier, 2011; Basu, Shivhare, & Singh, 2013) have shown a strong increase in the attention to natural sweeteners like stevia and xylitol for its sweetening qualities. Stevia or steviol glycoside, which is up to 200–300 times sweeter than sucrose, can be isolated from dried leaves of shrub *Stevia rebaudiana* (Guggisberg et al., 2011). Medical research has shown benefits of stevia in treating obesity and high blood pressure. It is also considered as an effective sugar alternative for those on low-carbohydrate diets such as diabetics (Manisha, Soumya, & Indrani, 2012). Currently, some attempts for manufacturing gelled systems with stevia such as mango jams (Basu et al., 2013) or yoghurts (Guggisberg et al., 2011) were made with promising results. Xylitol is a polyol, with

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a sweetening power similar to sucrose, found in fruits and vegetables (Prakash, Varma, Prabhune, Shouche, & Rao, 2011). The use of xylitol-containing products has resulted in defined reduction in teeth caries and represents interesting alternatives for high-caries-risk populations (Kandelman, 1997). Therefore, xylitol has important applications in pharmaceuticals and food industries (Sokmen & Gunes, 2006). Nevertheless, no information is at present available on the effect of xylitol on the viscoelastic properties of flour gelled systems.

Substitution of sucrose by other sweeteners can affect the system's viscoelasticity (Bayarri et al., 2004). When the sugar content of a product is changed, not only sweetness, but also food rheology and texture may be affected (Holm et al., 2009). From previous studies, it was obvious that sugars significantly influence the thermal properties of starchy materials, the effect depending on the sugar used, starch origin, and storage conditions (Tomasik, Wang, & Jane, 1995). In this sense, it was reported that addition of sucrose delayed the formation of gel networks of starch pastes from three waxy maize genotypes (Yuan & Thompson, 1998). Similar results were found for chestnut flour doughs in the presence of sucrose (Moreira et al., 2011). The presence of sugars can also modify the thermal stability of proteins (Fu & Rao, 2001). These authors explained the important role of the hydroxyl groups of sucrose in pectin gel formation and that sucrose may stabilise the structure or junction zones. Contrarily, other authors found that the addition of sugars can promote the protein weakening, indicating softening of the final products (Melander & Horváth, 1977). Many food products have optimal ranges of rheology and texture, and it is important to stay within these limits even when the sugar conditions are changed.

The development of alternative gluten-free desserts based on gelled systems from flours involves the understanding of how the complex mixture of flour and polysaccharides behave under food processing conditions. The final structure and textural properties of these systems are strongly dependent on processing temperature/time, cooling rates, polysaccharide content or pH conditions since they can affect the dynamic process of competition between phase separation and gel formation (Tolstoguzov, 1998; Nunes, Raymundo, & Sousa, 2006a). Hence, the objectives of the present work are to develop alternative gluten-free formulations from selected blends of chestnut flour (Cf) and whole rice flour (Rw), Agulha rice flour (Ra) or Carolino rice flour (Rc) and to investigate the effect of sucrose, stevia and xylitol on the gel-forming kinetics, final mechanical properties and microstructure of these systems using different experimental techniques.

2. Materials and methods

2.1. Raw materials

Two commercial gluten-free flours: chestnut flour (Cf) (Naiciña, Spain) and whole rice flour (Rw) (Próvida, Portugal) were studied. Other two rice grain sources, Agulha rice and Carolino rice, were used to obtain the corresponding flours, Ra and Rc, respectively, with comparative purposes. These materials were kindly supplied by the manufacturer (Novarroz, Portugal). Sucrose (table sugar), stevia (Raab Vitalfood GmbH, Germany) and xylitol (Raab Vitalfood GmbH, Germany) were employed. Xylitol powder used in this work has the same sweetness power as sucrose, whereas stevia powder is 200 times sweeter. All chemicals used for the preparation of samples for confocal laser scanning microscopy (CLSM) tests were of analytical grade. Rhodamine B and fluorescein isothiocyanate (FITC) were purchased from Sigma–Aldrich (St. Louis, MO, USA).

2.2. Sample preparation

Gels were prepared using chestnut flour (Cf) and each of the three rice flours (Rw, Rc, Ra) at several ratios (%) (Cf/Rf: 0/100, 20/80, 40/60, 50/50, 60/40, 80/20, 100/0). The formulations contained demineralised water at levels that provides total flour content of 20 and 30% (w/w). Flours were dispersed together with different sucrose content (5, 10, 15, 20, 25%, w/w), stevia or xylitol by stirring at 800 rpm for 10 min on a magnetic hotplate stirrer (Arex, Velp Scientifica, Italy) at room temperature. Equivalent sweetness of stevia and xylitol relative to tested sucrose concentrations were employed. Gels without and with sugars were prepared following the protocol developed in a previous work (Torres et al., 2013). Briefly, these suspensions were heated up to 90 °C and kept at this temperature for 30 min. Thereafter, samples were placed in a fridge in order to allow full maturation of the gels, which were kept at 5 °C for 24 h before performing texture and CLSM measurements. This time is enough to ensure the maturation of the gels structure. For rheological analysis, the aqueous suspensions were immediately loaded into the rheometer measuring system after 10 min stirring to promote gelatinisation heating and cooling in situ, avoiding further perturbations of the gel matrix.

2.3. Colour characterisation

The colour of all gels was measured instrumentally in a Chroma Meter CR-400 (Minolta Co., Osaka, Japan) tristimulus colourimeter with standard illuminant D65 and a visual angle of 2°. The colour parameters (L^*, a^* and b^*) were evaluated by CIELAB, where L^* defines the lightness and a^* (degree of redness or greenness) and b^* (degree of yellowness or blueness) are the chromaticity responsible parameters. At least ten measures were performed for each sample. Original colour parameters L_0^*, a_0^*, b_0^* were employed to calculate the total colour difference (ΔE^*) using the following expression,

$$\Delta E^* = \sqrt{(L^* - L_0^*)^2 + (a^* - a_2^*)^2 + (b^* - b_0^*)^2} \quad (1)$$

2.4. Texture characterisation

Firmness was determined from the texture profile analysis (TPA) using a TA-XTplus (Stable Micro Systems, UK) texturometer with a load cell of 5 kg, being the force resolution around of 0.1 g. Penetration measurements were carried out in the gels contained in a cylindrical flask (2.5 cm diameter and 4.5 cm height) filled up to about 90% i.e. 4 cm height of gel, using a cylindrical stainless steel probe of 11 mm diameter (5 mm of penetration and 2 mm/s of crosshead speed). The experiments were performed 24 h after preparation of the gels in order to allow full maturation of the samples. Gels were allowed to equilibrate at 20 °C for approximately 1 h in a temperature-controlled room before performing any measurements. Each formulation was measured at least in triplicate. Firmness (N) was considered as the maximum resistance to the penetration of the probe and was calculated as the height of the force peak during the first compression cycle (Bourne, 2002).

2.5. Rheological characterisation

Small amplitude oscillatory shear measurements were carried out on a RS-75 controlled stress rheometer (Haake, Germany) with temperature controlled by DC5 circulating water bath (Haake, Germany) and measured with a thermocouple attached to the stationary element. Serrated parallel plates (35 mm diameter and 0.500 mm gap) geometry was used to prevent wall slip effect as recommended by several authors (Barnes, Hutton, & Walters, 1989; Franco, Raymundo, Sousa, & Gallegos, 1998). Aqueous suspensions