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Novel mango bars using gellan gum as gelling agent: Rheological and microstructural studies

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ABSTRACT

This work aimed the development of mango bars, made with fresh mango puree and gellan gum. The influence of gellan concentration as well as the ratio of LA (low-acyl) and HA (high-acyl) gellan on the rheological and microstructural properties of the mango bars was studied. Rheological outcomes showed that both LA and HA, and in mixtures, were able to produce jellified products, within a rather low maturation time. Furthermore, a synergistic effect was observed at different ratios of LA/HA, enabling the production of mango bars with intermediate viscoelastic properties. Higher values of the dynamic moduli were perceived as the LA content increased. Confocal microscopy is in agreement with the rheological results, revealing a weakening of the gel structure with the increasing percentage of HA. Results suggest that 1 g of LA/HA 50/50 per 100 g of puree produces structures with suitable mechanical properties. However, the results need to be correlated to texture and sensory analysis, before proceeding to the next steps of product development.

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1. Introduction

Changes in modern lifestyle and the growing awareness of the link between diet and health, as well as new processing technologies, have led to a rapid rise in the consumption of fresh fruits products (O'Shea, Arendt, & Gallagher, 2012). Ready-to-eat fresh fruit products became an important area in the food industry due to their characteristics of freshness, low caloric content, and an active promotion of fruit as a basic component of a healthy diet (Corbo, Lanciotti, Gardini, Sinigaglia, & Guerzoni, 2000). Therefore, new trends in food industry require the development of new high quality convenient fruit products compatible with a healthy diet.

Fruit and vegetables are processed into a variety of products such as sliced minimally processed fruits, juices and concentrates, pulps and dehydrated products, jams and jellies, pickles, chutneys and fruit bars (Ahvenainen, 1996; Schieber, Wieland, & Reinhold, 2000). However, it is difficult to obtain a convenient product maintaining the desired stability from a chemical, enzymatic and microbiological point of view and presenting the nutritional and sensory attributes of a fresh product. A key factor on the development of new products relies on the selection of the type of fruits to be used, taking into account their physico–chemical and sensory properties and the characteristics of the desired final product.

Mango (*Mangifera indica* L.) is a popular and economically important tropical fruit throughout the world, due to its good texture, flavour, and high content of carotenoids, vitamin C, vitamin E, phenolic compounds, minerals and fibre, (Charles, Vidal, Olive, Filgueiras, & Sallanon, 2013; Vijaya, Sreeramulu, & Raghunath, 2010; Xiaolin et al., 2011). The consumption of mango can provide significant amounts of bioactive compounds with antioxidant activity. Its daily intake in the diet has been related to prevention of degenerative processes such as cardiovascular diseases and cancer (Alothman, Kaur, Fazilah, Bhat, & Karim, 2010; Liu, 2003; Sánchez-Robles, Rojas-Graü, Serrano-Odriozola, Gonsalez-Aguilar, & Martín-Belloso, 2009).

Mango has been processed into a large variety of products, such as juices, powders, purees and dehydrated slices (Dak, Verma, & Jaaffrey, 2007; Djantou, Mbofung, Scher, Phambu, & Morael, 2011; Ledeker, Suwonsichon, Chamber, & Adhikari, 2014; Sogi, Siddiq, & Dolan, 2015; Sriwimon & Boonsupthip, 2011). Furthermore, among the derivative mango products, mango bars or mango leathers are the most popular fruit bars in India. This mango bar is traditionally prepared by adding cane sugar, spreading the puree on bamboo mats and, drying it in the sun into

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leathery sheets (Vijayanand, Yadav, Balasubramanyan, & Narasimham, 2000). In addition, mango gels were developed using processed commercial mango juice and sodium alginate, with the addition of a calcium source (calcium orthophosphate) and a calcium sequestrant (glucono-δ-lactone) (Roopa & Bhattacharya, 2014).

Gellan gum, a polysaccharide approved as a food additive which has been used in a wide variety of food products including confectionary, jams, jellies, fabricated foods, hydrogels, pie fillings, puddings, ice cream and yogurt (Lau, Tang, & Paulson, 2000; Noda et al., 2008; Tang, Marvin, Tung, & Zeng, 1996) was chosen as gelling agent for the fresh mango bars. The native polymer, high acyl (HA) gellan, is an extracellular hydrocolloid secreted by the bacterium *Pseudomonas elodea*, and its linear structure is based on the tetrasaccharide repeating unit →4)-L-rhamnopyranosyl-(α-1 → 3)-D-glucopyranosyl-(β-1 → 4)-D-glucoronopyranosyl-(β-1 → 4)-D-glucopyranosyl-(β-1→, with O (2) L-glyceryl and O (6) acetyl substituents on the 3-linked glucose (García, Alfaro, Calero, & Muñoz, 2011; Noda et al., 2008; Yamamoto & Cunha, 2007). When exposed to alkali at high temperature, the acyl groups are hydrolysed and the deacylated form, low acyl (LA) gellan, is obtained.

HA gellan hydration is inhibited by the presence of sugars and high pH values; therefore, the hydration must be carried out in presence of less than 40 °Brix total soluble solids content (TSS) and at pH values below 4. By the contrary, LA gellan hydrates easily in the presence of sugars (up to 80 °Brix TSS), being its hydration much more dependent on the ions concentration, and generally it is not complete at pH values below 4 (Philips & Williams, 2009, chap. 9).

The gelation process of both gellan types is generally considered to involve two separate steps. In aqueous solutions, upon heating, the molecules of gellan are in a disordered coil state (single chain). Upon cooling the molecules adopt an ordered double helical conformation followed by associations between the helices through weak interactions such as hydrogen bonds and van der Waals forces (Matsukawa & Watanabe, 2007; Nickerson, Paulson, & Speers, 2003; Picone & Cunha, 2010). In the case of LA gellan, the helices aggregation are also promoted by pH reduction or mediated by cations, either by site binding between pairs of carboxylate groups on neighbouring helices or by suppressing electrostatic repulsion by binding to individual helices (Morris, Nishinari, & Rinaudo, 2012).

Generally, HA gels are thermally reversible without thermal hysteresis and set at temperatures around 70–80 °C; while the gel setting temperature of LA gels is around 30–50 °C showing significant thermal hysteresis, which extent is dependent on the nature and concentration of cations in solution (Philips & Williams, 2000, chap. 7; Williams & Philips, 1999; Rocha, Gonçalves, Bicho, Martins, & Silva, 2014).

One of the major advantages of gellan gum relies on the ability of LA and HA to produce gels with quite different characteristics. HA gellan usually produces elastic, soft, non-brittle and opaque gels and LA gellan enables the formation of non-elastic, hard, brittle and transparent gels (Ogawa, Takahashi, Yajinma, & Nishinari, 2006; Philips & Williams, 2009, chap. 9). Therefore, a wide range of structures, with varied rheological properties, appealing textures and good flavour release, may be designed by controlling the acyl content. The development of texturized fruit bars involves the understanding of synergism between gellan gum and mango puree. The final structure and textural properties of these systems are strongly dependent on gellan physicochemical properties (e.g. acylation degree), pH and composition of the puree (e.g. sugars, cations and fibre content), as well as on processing conditions such as gellan concentration, LA/HA ratio and temperature.

The influence of the addition of gellan gum (different concentrations and LA/HA ratios) to the mango puree was evaluated through analysis of the rheological (small amplitude oscillatory shear measurements) and microstructural (confocal laser scanning microscopy) properties in order to develop a new fresh mango bar.

2. Materials and methods

2.1. Materials

Two types of commercial gellan gum were kindly supplied by CP Kelco Corporation, Wilmington, USA: low-acyl gellan gum (Kelcogel® F) and high-acyl gellan gum (Kelcogel® LT). The composition of gellan gum powder was supplied by the manufacturer. LA gellan: carbohydrate (dietary fibre) 82 g/100 g; moisture 7 g/100 g; Ca^{2+} 252 mg/100 g; P 115 mg/100 g; Fe^{2+} 4 mg/100 g; Mg^{2+} 91 mg/100 g, Na^{+} 478 mg/100 g and K^{+} 4650 mg/100 g. HA gellan: carbohydrate (dietary fibre) 78 g/100 g; moisture 6 g/100 g; Ca^{2+} 259 mg/100 g; P 233 mg/100 g; Fe^{2+} 2 mg/100 g; Mg^{2+} 98 mg/100 g, Na^{+} 510 mg/100 g and K^{+} 1930 mg/100 g.

Mature mangoes (*M. indica* L. cv. Palmer) were purchased from a local supermarket in Lisbon, Portugal and selected based on firmness and integrity.

2.2. Methods

2.2.1. Preparation and analysis of fresh mango puree (control)

Mangos were stored at 5 ± 1 °C until processing (within 24 h). The fruit was then washed under running water, and manually peeled with a knife, cut into small pieces, and pureed in a food blender Vorwerk Thermomix TM-31 at 134 × g for 4 min at 22 ± 2 °C.

2.2.1.1. Determination of ash content. The total ash content was determined according to AOAC Official Method 923.03 (AOAC, 1990). A mass of 5 g of mango puree was weighed into a shallow dish and subjected to a temperature of 550 °C until light a grey ash was produced. The dish was then cooled in a desiccator and weighed soon after reaching room temperature. The total ash content was calculated using eq. (1):

$$\%\ \text{Total ash} = \frac{\text{ash weight}}{\text{original sample weight}} \times 100 \quad (1)$$

2.2.1.2. Determination of mineral content. The ash obtained according the method described previously, was dissolved in 3 mL concentrated nitric acid and then diluted to 25 mL with deionized water. The solution obtained was used to determine the mineral content using an atomic absorption spectrophotometer (UNICAM M series, UK). Six types of minerals were determined, potassium, calcium, magnesium, sodium, and iron. Phosphorus was assayed colorimetrically based on the reaction of phosphate with molybdovanadate complex (Windham, 1995). The minerals content was expressed in mg/100 g edible portion. The analysis was carried out in triplicate.

2.2.1.3. Determination of moisture content. A mass of 3 g of the mango puree (w_1) was placed in the oven for 6 h at 105 °C (in triplicate). After drying, the dried sample was weighed (w_2), and the moisture content was calculated using the following equation:

$$\text{Moisture concent}\ (\%) = \frac{w_1 - w_2}{w_1} \times 100 \quad (2)$$

2.2.1.4. Evaluation of pH and total soluble solids. The pH was determined using a pH meter BASIC 2° CRISON, Spain, calibrated

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