Food Hydrocolloids 69 (2017) 141–149

Contents lists available at ScienceDirect

Food Hydrocolloids

journal homepage: www.elsevier.com/locate/foodhyd

Microstructural characterisation and glycemic index evaluation of pita bread enriched with chia mucilage

M. de la P. Salgado-Cruz [a, b], M. Ramírez-Miranda [b], M. Díaz-Ramírez [c], L. Alamilla-Beltran [b], G. Calderón-Domínguez [b, *]

[a] Consejo Nacional de Ciencia y Tecnología (CONACYT), Av. Insurgentes Sur 1582, Col. Crédito Constructor, Del. Benito Juárez, C.P.: 03940, Ciudad de México, Mexico

[b] Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, Plan de Ayala y Carpio s/n. Col Santo Tomas, C.P. 11340, CDMX, Mexico

[c] Departamento de Ciencias de la Alimentacion, Division de Ciencias Biologicas y de la Salud, Universidad Autonoma Metropolitana, Unidad Lerma, Av. Hidalgo Poniente 46, Col. La Estacion, Lerma de Villada, Estado de Mexico, 52006, Mexico

A R T I C L E   I N F O

Article history:
Received 22 July 2016
Received in revised form
17 December 2016
Accepted 22 January 2017
Available online 30 January 2017

Keywords:
Pita bread
Chia mucilage
Microstructure
Gelatinisation
Glycemic index

A B S T R A C T

Chia seeds can be considered a functional food due to its soluble fibre (mucilage) that could be used to reduce the glycemic index in bakery products. Hence, the aim of this work was to evaluate the effect of chia mucilage on the structure of a flat bread (crumb and crust) and its relation to in-vitro glycemic index. Bread structure was evaluated by scanning electron (SEM), and confocal laser scanning microscopies. X-ray diffraction analysis and differential scanning calorimetry were also carried out. Results showed that the addition of fibre promoted changes in the starch structure, the crumb of all samples presenting the smallest X-ray diffraction peaks, higher gelatinisation degrees (100%), and both, amylose-lipid and B-type structures. Regarding the crust, it presented an A-type diffraction pattern and the least gelatinisation degree (48.75%). With respect to the glycemic index (eGI), different values were obtained depending on the section of the sample. In the crust, control bread presented higher values (73.2 ± 1.7, 69.4 ± 1.2%) than mucilage added bread (69.5 ± 1.9, 66.3 ± 0.7), while in the crumb section and for the whole bread, the eGI was higher for breads added with fibre (71.8 ± 1.1%, 70.0 ± 2.0%, 73.1 ± 0.42%). Gelatinisation enthalpy values from DSC, and SEM and confocal micrographs reinforced the eGI results. From this study it can be concluded that the presence of fibre on flat bread affects the degree of gelatinisation and the eGI, with the crumb of the bread having larger values; while at the crust, a portion of starch granules remained in their native state.

1. Introduction

Consumption of fibre has been related to the prevention of cardiovascular diseases and specifically to the reduction of glycemic index (GI). However, the effectiveness of fibre rich products, flours or pure dietary fibre to reduce the glycemic index is controversial, as well as the ideal type of fibre, and the amount that should be consumed (Scazzina, Siebenhandl-Ehm, & Pellegrini, 2013).

Dietary fibre has been classified as water soluble and water insoluble (Fendri et al., 2016), where the first one includes different types of substances such as β-glucans, gums, pectin, mucilage and arabinoxylans, and the second is mainly formed by lignin, cellulose and hemicellulose.

Both types of fibres have been tested in many starchy products such as bread, not only to reduce the glycemic response, but also to prolong freshness and to improve the bread quality (Fendri et al., 2016), but the effect on the glycemic index has been related to the presence of the soluble fraction where components such as arabinoxylans (Lu, Walker, Muir, Mascara & O′ Dea, 2000), or β-D glucans (Scazzina et al., 2013) seems to be responsible.

Soluble fibre can be obtained from almost all fruits, cereals, and seeds, varying the type and quantity of each compound. Fruits are rich in pectin, grains have β-glucans and arabinoxylans. (Abuajah, Ogbonna, & Osuji, 2015), while mucilaginous seeds, such as flaxseed or chia, have simple sugars such as xylose, arabinose, rhamnose, galactose, and glucose forming polysaccharides.

Global production of chia seed has increased mainly due to its healthy properties and popularity throughout the world (Muñoz,

* Corresponding author.
E-mail address: gcalderon@ipn.mx (G. Calderón-Domínguez).

http://dx.doi.org/10.1016/j.foodhyd.2017.01.027

Cobos, Diaz, & Aguilera, 2012). In 2009, chia seeds and grounded chia were approved as a novel food by the European Parliament and the European Council (Commission, E.U., 2009) for its inclusion in bread at a maximum level of five percent (5%) (European Commission, 2009), although this percentage was modified in 2013 (EC No 258/97, 2013).

The use of whole or ground chia seeds in breadmaking has been studied, evaluating the quality of the bread (Coelho & Salas-Mellado, 2015), the gelling (Coorey, Tjoe, & Jayasena, 2014), pasting and rheological properties (Inglett, Chen, Liu, & Lee, 2014a), the development of a gluten free bread (Costantini et al., 2014) or sugar cookies (Inglett, Chen, & Liu, 2014b), among others. Also, but in a smaller proportion, some studies about the glycemic index, postprandial glycemia or cardiovascular risk factors related to starchy products such as bread (Vuksan et al., 2010) or tortilla (Rendón-Villabobos, Ortíz-Sánchez, Solorza-Feria, & Trujillo-Hernández, 2012) added with chia seed or flour have been carried out, but their results were inconclusive (Souza-Ferreira, Souza-Fomes, Santo da Silva, & Rosa, 2015). However, the number of published studies regarding the use of chia mucilage in bread making is null.

Chia mucilage is expelled from the seed epidermis coat as it comes in contact with water, forming 18–45 nm width fibres (Salgado-Cruz et al., 2013). Its solubility (10 g L^{-1} w/v water) is higher than that of guar and xanthic gums (Capitani, Ixtaina, Nolasco, & Tomás, 2012), which makes it an interesting ingredient to be applied in breadmaking to improve the quality of bread and to reduce the glycemic response (Fardet, Leenhardt, Lioger, Scalbert, & Rémésy, 2006).

Glycemic response (GR) can be evaluated by two methodologies: in-vitro and in-vivo analysis.

In vitro methods have been developed for estimating the GR of foods. These methods are based on the rate of starch digestion, which provides the predicted or estimated glycemic index (eGI), but do not consider the metabolic responses of the human body (Capriles & Areas, 2016). Taking these limitations of in vitro studies, this kind of analysis provides insight for future in vivo trials.

However, as the GR is based on the starch digestion, and in bread making this carbohydrate is the main component, all the changes that the granular structure presents during the thermal process could affect the rate of digestion of starch and thus also affect the absorption of glucose in the small intestine (Svihus & Hervik 2016). In this regard, Schuchardt et al. (2016) published that the presence of soluble fibre, like glucan and inulin at high concentration and glucans and pentosanes (NSPS) linked to starch in bread baking products, impedes starch gelatinisation and thus enzymatic vulnerability, lowering the glycemic index. They followed the changes in the starch granule structure by microscopy techniques.

Structural changes of starch during thermal process in breadmaking have been studied by different techniques (Karim, Norziah, & Seow, 2000), which include light microscopy (Fleming & Sosulski, 1978), epiflourescence microscopy (Peighambardoust, Dadpour, & Dokouhaki, 2010), visible and near-infrared reflectance spectroscopy (Xie, Dowell, & Sun, 2004), X-ray diffraction analysis (Dragsdorf & Varriano-Marston, 1980), differential scanning calorimetry (Srikaeo, Furst, Ashton, Hosken, & Sopade, 2005), and others. Some of these techniques, such as X-ray diffraction analysis (DRX) or differential scanning calorimetry (DSC), provide quantitative information, while others like scanning electron microscopy (SEM) or confocal laser scanning microscopy (CLSM) result in micrographs with easily observed qualitative information about structural changes. Regarding CLSM, this technique also allows simultaneous observation of main bread components (starch and protein), as well as the following of structural changes on wheat dough or bread during processing (Blonk & Aalst, 1993).

Most of structural bread making studies have been applied to bread, which can be prepared with different ingredients (wheat, maize, rice, barley, rye, sorghum and millet) and process conditions that give rise to different products (flats, integral, leavened, etc). However, most of the research regarding glycemic index has been carried out in white yeasted bread in which a low temperature (180–210 °C) and long time baking process (20–40 min) are required.

Pita bread is a flat bread highly consumed in the Middle East, North Africa and Central Asia (Al-Dmoor, 2012; Liljeberg, Granfeldt, & Björck, 1994), with a very low crumb proportion, and produced under a high temperature -short time baking process (HTST), having the possibility of presenting a low glycemic index as a result of its processing conditions (Indrani, Swetha, Soumya, Rajiv, & Venkateswara, 2011; Izydorczyk et al., 2008; Smitha et al., 2008). Hence, the aim of this work was to study the changes in the microstructure of pita bread enriched with chia mucilage, and their relation to starch gelatinisation and glycemic index.

2. Materials and methods

2.1. Bread making process

Pita bread was prepared by adapting the methods reported by Maleki and Daghir (1967), Qarooni, Orth, and Wootton (1987) and Farvilli, Walker, and Quarooni (1995). Commercial wheat flour (100 g, Osasuna, Elizondo S.A. de CV, Miguel Hidalgo, DF, México, Alveographic deformation energy: 300×10^{-4} J; 11.56 g protein/100 g sample (db)) was mixed with 3 g of sugar (Great Value, Walmart, Bentonville, AR, USA), 1.5 g of salt (La Fina, Sales del Istmo, S.A. de C.V, S.A. de C.V, Coatzacoalcos, Veracruz, México), 1.0 g of instant yeast (Nevada oro; Safmex, S.A. DE C.V./Fermex, S.A. DE C.V, Toluca, Estado de México) and the quantity of water (Bonafont, Liquimex S.A. de C.V., Toluca, Estado de México, México) required to reach the recommended farinographic consistency (850–900 BU) necessary to obtain a good quality Pita bread (Qarooni et al., 1987). Dough was mixed (12 min) in the Simon extensometer mixer (Henry Simon Limited, Stockport, Cheshire, UK). Then dough was fermented (30 min/30 °C), cut in 10 g portions, and laminated (Atlas Wellness 150 Pasta Maker, Stainless Steel, USA) to obtain a sample of pita bread dough (4 cm diameter and 6–7 mm thickness). Finally, the samples were baked at 530 °C for 30 s in a muffle furnace (Thermoline FB1415M, Thermo-Fisher Scientific Inc, Waltham, MA, USA).

Chia mucilage was obtained as described by Salgado-Cruz (2013) and incorporated as a functional ingredient (2 g per 98 g of wheat flour) in pita bread formulation, which was elaborated as described for control bread, only varying the quantity of water, being 53 mL for control bread, and 56 mL for bread with the chia mucilage.

After baking, bread samples were cooled up to reach room temperature (20–22 °C, 2 h approximately) and then immediately prepared to be analysed or stored for subsequent analysis. In all cases, samples were separated in two sections: top and bottom, and these sections were also divided in two: crumb and crust, resulting in 4 subsamples (Fig. 1).

Based on the test to be performed, and mainly to have the same moisture content (5–6%), some subsamples were immediately freeze-dried after baking, packed in sealed low density polyethylene bag (Ziploc, Johnson & Son, Inc, Racine, Wisconsin 53403-5011 USA), and kept in a desiccator until analysis, while the other subsamples were immediately analysed (Confocal laser scanning microscopy).

Based on literature reports (Alhusain, Tóth, Rakusz, Almási, & Farkas, 2004; Rubenthaler & Faridi, 1981), baker's experience and