LWT - Food Science and Technology 77 (2017) 100–109

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Evaluation of *Agave angustifolia* fructans as fat replacer in the cookies manufacture

Patricia A. Santiago-García [a], Erika Mellado-Mojica [b], Frank M. León-Martínez [a], Mercedes G. López [b, *]

[a] Instituto Politécnico Nacional, Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional - Unidad Oaxaca, Santa Cruz Xoxocotlán, C.P. 71230, Oaxaca, Mexico

[b] Departamento de Biotecnología y Bioquímica, Centro de Investigación y de Estudios Avanzados del IPN-Unidad Irapuato, C.P. 36821, Irapuato, Gto., Mexico

ARTICLE INFO

Article history:
Received 3 May 2016
Received in revised form
11 November 2016
Accepted 12 November 2016
Available online 14 November 2016

Keywords:
Agave angustifolia fructans
Fat mimetic
Technological properties
Viscoelastic behavior
Cookies
Wheat flour dough

ABSTRACT

Despite the popularity of agave fructans as a new prebiotic and a functional food ingredient, little is known of its technological properties. This study aims to analyze the technological functionality of *Agave angustifolia* fructans of the long degree of polymerization as a fat replacement at 10, 20 and 30% of the fat substitution in the cookie production. Rheological measurements, chemical composition, functional properties and sensory evaluation were evaluated. The critical strain value of the linear viscoelastic region was reduced as agave fructans content increased, producing a brittle flour dough, with a predominantly elastic behavior. Sensory data reported similarities in the quality characteristics of cookies containing agave fructans up to 20% replacement respect to control cookies. HPAEC-PAD results showed the presence of agave fructans in the baked products. FT-IR spectra of cookies exhibited strong differences in absorption bands at 2900, 1700, 1150 and 936 1/cm, corresponding to fatty acids, carbohydrates and fructans region. Principal component analysis allowed the classification and discrimination of cookies according to their agavins percent as fat replacement. To conclude, agavins exerted a positive contribution as a fat replacer with nutritional advantages, such as, low caloric content, prebiotic capability and contributing to reducing the energy intake in humans.

1. Introduction

The worldwide health issues (obesity and metabolic disorders) have opened the eyes of consumers to ingest fiber-enriched foods. Fuctans, fructose polymers with β(2-1) and/or β(2-6) linkages, are stored as reserve carbohydrates in 15% of flowering plants (Kaur & Gupta, 2002; Van den Ende, Peshev, & De Gara, 2011) are classified as dietary fibers with prebiotic capacity recognized as safe (GRAS) by the FDA (Franck, 2002). *Agave angustifolia* store complex mixtures of graminans and highly branched neofructans defined as agavins (Mancilla-Margalli & López, 2006). These agavins have the capacity to promote the growth of bifidobacteria and lactobacilli, as well as to stimulate the secretion of peptides involved in appetite regulation demonstrating their prebiotic potential (Santiago-García & López, 2014).

Fructans exhibited some interesting technological properties according to their degree of polymerization, as a low-calorie sweetener, fat replacer, emulsifier and texturizer (Tungland & Meyer, 2002).

The technological functionality of inulin-type fructans as a fat replacer in bread, cookies, yogurt, and dairy products has been extensively described (Akin, Akin, & Kirmaci, 2007; Handa, Goomer, & Siddhu, 2012; Kip, Meyer, & Jellema, 2006; Peressini & Sensidoni, 2009; Zoulias, Oreopoulou, & Tzia, 2002). However, the technological applications of agavins as functional food ingredients has hardly been studied (Crispín-Isidro, Lobato-Calleros, Espinosa-Andrews, Alvarez-Ramírez & Vernan-Carter, 2015).

Currently, consumers' attention are drawn towards low-caloric products, owing to the increasing emphasis on health education. Agavin type fructans are soluble carbohydrates and can also be used to give a fat mimetic effect in some foods, thereby, generating a new functional food product. However, their effects on technological and functional properties have to be evaluated and the prevalence of these molecules has to be ensured in the final product, otherwise, there will be no prebiotic effect.

* Corresponding author. Km. 9.6 Lib. Norte Carretera Irapuato-León, Irapuato, Gto., AP. 629, CP. 36821, Mexico.
E-mail address: mlopez@ira.cinvestav.mx (M.G. López).

http://dx.doi.org/10.1016/j.lwt.2016.11.028
0023-6438/© 2016 Published by Elsevier Ltd.

Chromatographic and spectroscopic techniques are successful tools for the authentication and quality of many food products. HPAEC-PAD is the most common technique used for oligosaccharides profiling analyses, which have been used in the characterization of juices, natural syrups, and prebiotic carbohydrate fingerprinting (Megherbi, Herbreteau, Faure, & Salvador, 2009; Mellado-Mojica & López, 2012, 2015; Willems & Low, 2014). The spectra from the FT-IR region coupled to the Chemometrics are commonly used for structural identification (fingerprinting) of organic compounds, such as lipids, proteins, carbohydrates, and polysaccharides in a large variety of food products (Cozzolino, 2012; Guillen & Cabo, 1997; Rodriguez-Saona & Allendorf, 2011).

The rheological (dynamic test) and mechanical properties of biscuits are salient quality attributes, as they have a direct impact on the sensory perception and thereby on the consumer acceptance of such products. Fat is one of the principal ingredients that is affecting cookies texture since the aeration levels can vary their final volume (Drewnowski, Nordensten, & Dwyer, 1998; Maache-Rezzoug, Bouvier, Allaf, & Patras, 1998; Manley, 2000; Pareyt & Delcour, 2008; Pareyt et al., 2009; Zoulias, Oreopoulou, & Tzia, 2002). Likewise, fat impact shortening, richness, and tenderness, to improve flavor and mouthfeel, a factor that can be affected by the partial substitution of it (Pareyt & Delcour, 2008; Pareyt et al., 2009). Therefore, the aim of this work was to evaluate the technological application of *Agave angustifolia* fructans of the large degree of polymerization (AALDP) as a potential fat replacer in the cookies production and their sensory acceptability.

2. Materials and method

2.1. Extraction of Agave angustifolia fructans of the long degree of polymerization

Eight years old plants of *Agave angustifolia* were collected from Totolapan, Oaxaca, Mexico. Fructans were extracted according to the method established by Mancilla-Margalli and López (2006) with some modifications. Briefly, 100 g of the stem were twice extracted with 100 mL of distilled water. Fructans extraction was carried out at 80 °C for 40 min and the final solution was clarified through an activated charcoal, diatomaceous earth, and demineralized couplet to a cation exchange resin. *Agave angustifolia* fructans of the long degree of polymerization (AALDP) was separated by precipitation with ethanol absolute. AALDP were spray dried and stored in a desiccator until use.

2.2. Cookies manufacture

Cookies were prepared according to the following procedure: Butter was mixed with sugar; the egg, condensed milk (is used to sweeten and give elasticity) and AALDP (fat mimetic) were added directly to the blended fat and mixed with other ingredients. Wheat flour and milk powder were sifted together and added to the cream. All the ingredients were blended in a Philips mixer for 6 min, until a cream was formed. The dough was formatted to 4 cm diameter and 1.0 cm height cookies (using a frame of 1 cm height), which were baked in an air circulating oven at 200 °C for 20 min. Four cookie group according to their fat replacement percent were obtained (FR_0%, FR_10%, FR_20% and FR_30%), dough formulations are described in Table 1. After 5 min to the end of the mix, 10 g of dough was analyzed in the rheometer. The dough and cookie samples were prepared by triplicate and the reported data are the mean of them. Taken into account the ratio of fat to flour and sugar to flour, our dough corresponds to a short-dough (sheeted) (Manley, 2000). The prepared cookies were subjected to an instrumental and sensory analysis, 24 h after baking.

Table 1
Formulations of different short-dough cookies (on flour weight base) supplemented with *Agave angustifolia* fructans of long degree of polymerization as a fat mimic substance.

Ingredient	Unit	FR_0%[a]	FR_10%[a]	FR_20%[a]	FR_30%[a]
Wheat flour	%	43	43	43	43
Egg white	%	4	4	4	4
Sucrose	%	21	21	21	21
Milk powder	%	4	4	4	4
Butter	%	24	21.6	19.2	16.8
Condensed milk	%	4	4	4	4
Leavening powders	%	0.25	0.25	0.25	0.25
AALDP[b]	%	0	2.4	4.8	7.2

[a] Sample's code, FR means "fructan", it is followed by one number and the symbol % that give the quantity of fat that was replaced by the agavins on weight basis.
[b] AALDP, *Agave angustifolia* fructans of long degree of polymerization.

2.3. Rheological measurements of cookie dough

The rheological properties of each cookie dough formulation (FR_0%, FR_10%, FR_20% and FR_30%) were measured using two levels (23.7% and 30.9%) of dilution on a weight basis of the dough with cow milk. It was made in order to ease the sample load and enhance the contact between the sample and measuring plates. Rheological measurements were taken under controlled stress rheometer Physica MCR 301 (Anton Paar, Austria) using a parallel plate geometry of 50 mm in diameter. A gap of 1 mm was considered and the temperature was controlled by a Peltier system at 25 ± 0.1 °C. After the loading of the sample, a tempering time of 120 s was used to reach the desired temperature.

A stress sweep test in oscillatory shear mode was carried out using an angular frequency of 10 rad/s. The shear stress was increased in a logarithm ramp from 0.1 to 150 Pa. From this test the following rheological properties were calculated: the oscillatory yield stress by determining the flexion point in a log (storage modulus, G') versus log (shear stress) plots; the flow stress by determining the crossover point of the viscoelastic moduli ($G' = G''$); the linear viscoelastic region (LVR) using the down inflection point of G' (5% of deviation of the linear region) versus shear strain plots. The software Rheoplus v. 3.0 (Anton Paar) was used in the analysis.

2.4. Agave angustifolia fructans identification in the cookies by high-performance anion-exchange chromatography with pulsed amperometric detection (HPAEC-PAD)

The AALDP in the cookies were identified and analyzed by HPAEC-PAD, according to the method established by Mellado-Mojica and López (2012, 2015) using an ion chromatography Dionex ICS-3000 (Dionex Corp., USA) with a guard column CarboPac PA-100 (4 mm × 50 mm) and an analytical column CarboPac-PA100 (4 mm × 250 mm). 10 mg of lyophilized cookie was suspended in 10 mL of deionized water (resistivity of 17 MΩ) and then filtered through a nylon membrane of 0.45 μm before injection. 25 μL of the diluted samples were injected in the HPAEC-PAD. The separation of the carbohydrates was made with a gradient of sodium acetate in 0.15 M of NaOH with a flow of 0.8 mL/min and 25 °C of column temperature. The potential applied for detection by the amperometric pulse were E1 (400 ms), E2 (20 ms), E3 (20 ms) and E4 (60 ms) of +0.1, −2.0, +0.6 and −0.1 V, respectively. HPAEC-PAD chromatograms were collected in the Chromeleon software (Dionex Corp., USA).