Food Hydrocolloids 43 (2015) 73–81

Contents lists available at ScienceDirect

Food Hydrocolloids

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

Impact of soluble dietary fibre on the characteristics of extruded snacks

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ARTICLE INFO

Article history:
Received 25 November 2013
Accepted 29 April 2014
Available online 15 May 2014

Keywords:
Inulin
Cereals
Functional products
Extrusion-cooking
Rheology

ABSTRACT

The aim of this experimental work was to evaluate the effect of inulin addition on dough rheological properties, texture and sensory quality of extruded snacks. Two commercial fructan products of different degree of polymerisation (DPn) were used at levels from 2% to 7% (DPn = 10 for inulin GR; DPn = 23 for inulin HPX). Dough rheological properties were investigated using dynamic measurements in the linear viscoelastic range (frequency sweep and time cure tests) and farinograph test. Colour, specific volume (Vs), mechanical and sensory properties of snacks were evaluated. Fibre enrichment lowered dough consistency due to a reduction in water absorption. Large differences in elastic properties of samples were observed between 25 and 95 °C due to incompatibility between inulin and starch and different kinetics of starch gelatinization. The magnitude of G' decreased with the increase in fibre content and GR had a greater effect than HPX. Inulin GR increased product expansion and hardness compared with the reference. No significant differences in Vs and mechanical properties were observed between reference and inulin HPX enriched samples up to 5%, while lower values were observed at 7%. Short-chain inulin lowered the extent of non-enzymatic browning. Snacks made with 5% inulin HPX can be used to enhance the fibre content without impacting negatively on product quality.

1. Introduction

Over the last decades consumer demands in the field of food production have changed considerably. For this reason, foods today are not intended only to satisfy hunger and to provide necessary nutrients, but also to prevent nutrition-related diseases and enhance physical and mental well-being of consumers (Betoret, Betoret, Vidal, & Fito, 2011; Brouns & Vermeer, 2000). Functional foods play an outstanding role. In particular, dietary fibre (DF) have been the subject of considerable attention by researchers due to the potential benefit in reducing coronary heart-related diseases, diabetes incidence and gut neoplasia (Anderson et al., 2009). Recently, research attention has focussed on the use of soluble DFs such as inulin-type fructans. Inulin-type fructans are a linear polydisperse carbohydrate material consisting mainly of D-fructose joined by β-(2 → 1) linkages (Roberfroid, 2005). The last fructose may be linked with a glucose by an α-(1 → 2) bond as in sucrose. The main sources of inulin that are used in food industry are chicory and Jerusalem artichoke. Native chicory inulin is a non-fractionated inulin extracted from fresh roots that always contain glucose, fructose, sucrose and small oligosaccharides. The degree of polymerisation (DP) of chicory fructans varies from 2 to 60 (average DP = 12) and about 10% of the fructan chains in native DF have a DP ranging between 2 and 5 (Roberfroid, 2005). Several studies have identified beneficial attributes of inulin such as stimulation of colonic bifidobacteria and lactobacilli (prebiotic activity), improvement of bowel function, increased calcium absorption, positive effects on glucose and lipid metabolism and stimulation of immune system (Biedrzycka & Bielecka, 2004; Roberfroid, 1993, 2005).

Most studies reported the effects of inulin supplementation on dough rheological properties and on the quality of products such as pasta and bread (Aravind, Sissons, Fellows, Blazek, & Gilbert, 2012; Brasil et al., 2011; Brennan, Kuri, & Tudorica, 2004; Frutos, Guilabert-Anton, Tomas-Bellido, & Hernandez-Herrero, 2008; Mastromatteo, Iannetti, Civica, Sepielli, & Del Nobile, 2012; Morris & Morris, 2012; Peressini & Sensidoni, 2009). Limited information is available on influence of inulin enrichment on the quality of extruded snacks (Brennan, Monro, & Brennan, 2008). Inside the extruder the cereal mixture is heated above the starch gelatinisation temperature leading to a cooked product, that may be directly enrobed and flavoured, or needs further processing such as frying,

Abbreviations: G', storage modulus; G'', loss modulus; tan δ, loss tangent; d.b., dry basis; Vs, specific volume; DP, degree of polymerisation; RS, resistant starch.

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http://dx.doi.org/10.1016/j.foodhyd.2014.04.036

roasting, etc. (de Cindio, Gabriele, Pollini, Peressini, & Sensidoni, 2002; Matz, 1984; Peressini et al., 2002).

Manufacturing high-DF products are directly related to technological changes and maintenance of desired sensory properties. DF addition in extruded cereals most often leads to detrimental effects on product quality due to reduced expansion volume, increase in density and hardness, and decrease in crispness (Robin, Schuchmann, & Palzer, 2012). The deleterious effects of various fibres depend greatly on DF properties and inconsistent effects were frequently reported. Soluble fibres such as inulin gave a higher expansion and more favourable texture than insoluble fibres such as cereal bran (Brennan et al., 2008). Differences in expansion volume between soluble and insoluble fibres can be attributed to differences in water absorption, viscoelastic properties of the dough at the exit of the extruder die and stabilisation of the bubble membrane during bubble growth. Inulin at 10% did not induce changes in bulk density of snack products (Brennan et al., 2008). On the contrary, Robin et al. (2012) reported that the effect of soluble fibre content on expansion properties of extruded cereals is unclear, while increasing insoluble fibre appeared to systematically decrease sectional expansion and increase bulk density. Indeed, effect of fibre addition does not only depend on the content, but also on the polymer molecular weight and structure. The type of cereal ingredient to which the fibre is added, also appears important. Unlike for wheat fibre, the use of 10% inulin in extruded corn starch did not influence cell dimension and number (Brennan et al., 2008). Texture of extruded products depends mostly on starch–fibre interaction (Robin et al., 2012). An increase in breaking force of corn flour products with the increase in bran content was observed, while inulin addition gave slight changes (Brennan et al., 2008).

Extrusion-cooking of snack foods is a high temperature and shear process that can determine a loss of functional ingredients added to the formulation. Consequently, it is crucial to monitor the retention level in the final product. The impact of food processes on inulin degradation has been poorly investigated mainly in model systems (Böhm, Kaiser, Trebstein, & Henle, 2005; Glibowski & Bukowska, 2011; Glibowski & Wasko, 2008; Klewicki, 2007; Matusek, Merész, Le, & Örsi, 2009). The severity of functionality loss was affected by the processing conditions and aggravated by a low pH and heating. Moreover, yeast invertase induces inulin degradation to fructo-oligosaccharides or fructose.

The aim of this experimental work was to evaluate the potential use of inulin as a fibre enriching ingredient in ready to eat snack food products. The effects of various commercial inulin products on dough properties and snack quality were evaluated using rheological, physico-chemical and sensory analyses. The quantitative changes in inulin after processing (cooking-extrusion-roasting) were also determined.

2. Materials and methods

2.1. Materials

Commercial wheat flour (12.5% moisture, 11.0% protein) (Molino Munari, Italy), defatted soy flour (7.0% moisture, 57.2% protein, 12.0% starch) (Cargill, Belgium), corn starch (13.0% moisture, 0.4% protein, 86.3% starch) (Roquette, France), rice flour (12.4% moisture, 7.3% protein, 79.2% starch) (Pasini, Italy), corn grits (11.8% moisture, 8.0% protein, 69.0% starch) (NDF Atzeca Milling Europe, Italy), sugar and salt were used. Two inulin products from chicory of different degree of polymerisation (DP) were supplied by Orafti Food Ingredients (Belgium): Raftiline® HPX (inulin HPX, DP = 23) and Raftiline® GR (inulin GR, DP = 10). Sugar content (glucose, fructose and sucrose) was 0.5% d.b. and 12% d.b. for inulin HPX and GR, respectively. Resistant starch (Hi-Maize 260) was provided by National Starch & Chemical Limited (UK).

2.2. Product formulation

The snack product formula contained wheat flour (25% w/w), defatted soy flour (25% w/w), corn starch (25% w/w), rice flour (10% w/w), corn grits (10% w/w), sugar and salt (5% w/w) (reference). Fibre-enriched blends contained 2, 5 and 7% (w/w) inulin (7.0% moisture content) were made by replacing defatted soy flour with fibre because of its low starch content. Starch is important for snack expansion and for this reason it was avoid to replace other ingredients such as wheat flour, rice flour, corn starch and grits, which contain high starch levels.

Dry flour blends containing all the ingredients were prepared by means of a traditional flour ribbon mixer and were used for rheological measurements and snack production.

2.3. Snack production

The dry flour blend was hydrated to 32% moisture content using a mixing vessel equipped with a micrometric pump for the water and a high speed pre-mixer. The dough was fed to a single screw, low shear cooker-extruder (30 kg/h) with a four step configuration of the screw and thermo-controlled sections of the barrel (G 55 model, Pavan, Galliera Veneta, PD, Italy). Temperatures of the four sections were 85, 145, 145 and 135 °C. Screw speed was 50 rpm. No die was put on the head and the unshaped dough went to feed a single screw former extruder (F 55 model, Pavan) with a round grids shaped die. The barrel and the head were equipped with a water cooling circuit. The screw speed was 25 rpm, head temperature 45 °C and head pressure 190 bar.

Shaped product (round grids) was dried at a maximum temperature of 60 °C for 8 h in a static dryer (SD 100 model, Pavan) and roasted at 230 °C for 30 s (HTST equipment, BTO 50 model, Pavan). The moisture content of dried products was about 10.5%.

2.4. Mixing properties

Mixing properties of the dough were evaluated using a farinograph equipped with a 100 g bowl (T6 Promylograph Max Egger, Austria). The dry flour blend (80 g) and water (50%, on 14% moisture flour basis) were mixed for 20 min at 30 °C and changes in dough consistency (PU) were recorded during mixing.

In order to compare water absorption of defatted soy flour and inulin, the amount of water (%, on 14% moisture flour basis) required to reach a dough consistency of 500 PU (farinograph water absorption) was evaluated for the following blends: a) wheat flour (33.3%, w/w), corn starch (33.3%, w/w), rice flour (13.3%, w/w), corn grits (13.3%, w/w), sugar and salt (6.8%, w/w) (WCR); b) sample WCR (93%, on 14% moisture basis) and defatted soy flour (7%, on 14% moisture basis) (WCR-7% soy flour); c) sample WCR (93%, on 14% moisture basis) and inulin GR (7%, on 14% moisture basis) (WCR-7% inulin GR); d) sample WCR (93%, on 14% moisture basis) and inulin HPX (7%, on 14% moisture basis) (WCR-7% inulin HPX).

2.5. Dynamic rheological properties

Rheological measurements were carried out using a controlled stress rheometer (SR5, Rheometric Scientific, Germany) equipped with serrated parallel plate geometry (25 mm diameter, 2 mm gap). Doughs at 50% water absorption were mixed for 12 min in the farinograph until maximum development, immediately removed from the bowl and placed between the plates of the rheometer.