Journal of Food Engineering 162 (2015) 1–8

Contents lists available at ScienceDirect

Journal of Food Engineering

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

Evaluation of rheological, physicochemical, thermal, mechanical and sensory properties of oat-based gluten free cookies

Denisa Eglantina Duta, Alina Culetu *

National Institute of Research & Development for Food Bioresources – IBA Bucharest, 6 Dinu Vintila Street, 021102 Bucharest, Romania

ARTICLE INFO

Article history:
Received 24 December 2014
Received in revised form 7 March 2015
Accepted 4 April 2015
Available online 9 April 2015

Chemical compound studied in this article:
Beta-glucan (PubChem CID: 46173706)

Keywords:
Oat flour
Oat bran
Gluten-free cookies
β-Glucan
Electronic-nose
Mixolab

ABSTRACT

Oat bran (OB) is a high fibre source with human health benefits. Gluten-free cookies were prepared by incorporation of OB (0%, 30%, 50%, 70% and 100%) into oat flour (OF).

Dough rheology for OF/OB mixtures indicated no change in starch gelatinization and retrogradation between 30% and 70% OB when compared with OF. OB incorporation increased protein weakening and decreased the stability of gelatinized starch. Cookies were evaluated based on thermal properties and the enthalpy decreased by 60%. SEM revealed differences in internal structure of the cookies and e-nose technique provided a good discrimination of cookies based on the overall flavour. The highest β-glucan content (4.37% dm) was achieved in the 100% OB cookies with an overall acceptability of 5.6. Incorporation of OB provided darker samples and cookies become more brittle (hardness was reduced to 18.33 N).

Results showed that OB can be used to enhance the nutritional properties of gluten-free oat cookies.

1. Introduction

Celiac disease is a chronic inflammatory disorder in genetically susceptible subjects, characterized by damage of the small intestinal mucosa caused by gluten (Catassi and Fasano, 2008). In the past years interest in foods that may help to gluten-free diets was considered (Gallagher et al., 2004). Oats represent a healthy alternative for starch-based ingredients in gluten-free and normal diets too, owing to the high content of fibre, essential amino acids, unsaturated fatty acids, vitamins, minerals and bioactive compounds (Hüttner and Arendt, 2010; Pawłowska et al., 2012; Hager et al., 2012a,b; Arendt and Zannini, 2013). Long-term clinical studies on treated celiac adults with a daily intake of a median of 20 g of oats showed no damage in small-bowel mucosal villous, inflammation or gastrointestinal symptoms, but it provided a higher daily intake of fibre (Kaukinen et al., 2013).

Oat is a well-known source of soluble dietary fibre β-glucan that is composed of glucose molecules in long linear glucose polymers with mixed β-(1 → 4) and β-(1 → 3) links. β-Glucan is known to lower cholesterol and glucose in blood (Butt et al., 2008; Jenkins et al., 2002). Health claims related to oats and referred to the reduction of cholesterol levels are reported by the US Food and Drug Administration and EU (FDA, 2003; EFSA, 2009).

β-Glucan together with other phytochemicals are concentrated in the bran layer of oat grain that provide functional properties to the bran. Different researches reported on beneficial effects of oat bran. Thus, the efficiency of oat bran in decreasing serum total cholesterol and promoting bile acid excretion was investigated in rats for 6 weeks (Drzikova et al., 2005). Similar, an oat bran-fortified diet (27%) in 4 week study on mice was correlated with 19% lower plasma cholesterol and 40% higher excretion of bile acids (Andersson et al., 2013). Also in a mice model, Andersson et al. (2010) demonstrated the effects of oat bran on plasma cholesterol, markers of inflammation, eNOS expression and development of atherosclerosis. Moreover, in a 2-week crossover study focused on young healthy volunteers, oat bran (102 g/day) showed a decrease in total cholesterol by 14% and non-HDL cholesterol by 16%, as well as in total triacylglycerol by 21% and very-low-density lipoprotein triacylglycerol by 33%. Also, it was revealed that oat bran may affect energy balance through reduced energy utilization (Kristensen and Bügel, 2011). Another study with premenopausal women who received 28 g oat bran/day (during 4 weeks) showed beneficial effect on plasma HDL level (a mean increase of 11.2%) and a decrease by 7% in the total cholesterol/HDL ratio (Robitaille et al., 2005).

The successfully incorporation of oat bran into cereal foods has been reported (Sibakov et al., 2013). Oat bran has been added in

* Corresponding author. Tel./fax: +40 31 620 58 33.
E-mail addresses: alinaculetu@gmail.com, alina.culetu@bioresurse.ro (A. Culetu).

http://dx.doi.org/10.1016/j.jfoodeng.2015.04.002
0260-8774/

combination with wheat flour to increase the dietary intake in fibre-rich biscuits (Sudha et al., 2007). Hence, oat bran applicability is limited because of its high lipid content (Sibakov et al., 2013).

The general objective of this paper was to produce a detailed study on the nutritional quality of gluten-free cookies based on oat flour and oat bran. More exactly, the aim was to evaluate the effect of different level of oat bran incorporation in oat flour on the rheological behaviour of the dough as well as the overall quality of gluten-free oat based cookies. The effects of oat bran on the thermal characteristics, morphology, physical properties (colour and texture) of the cookies were also investigated. The results were compared to control cookies without oat bran addition. Moreover, an electronic nose system was used to discriminate among the overall volatile composition of the cookies.

2. Materials and methods

2.1. Materials

Gluten free oat flour (OF) and gluten free oat bran (OB) (gluten content < 40 ppm, ELISA method, using Ridascreen® Gliadin Kit from R-Biopharm AG, Darmstadt, Germany) were purchased from Glebe Farm Foods Ltd (United Kingdom). Proportions of the fractions > 400 μm, 180–400 μm and <180 μm were 42.2%, 15.5%, 42.3% for OF and 98.6%, 0.9%, 0.5% for OB, respectively. Commercially available sugar, eggs, shortening, citric acid, sodium and ammonium bicarbonate were used for the study. All chemicals and reagents were of analytical grade.

2.2. Compositional analysis

The characteristics of the oat flour/bran and cookies were determined as follows: protein content by the Kjeldahl method with a conversion factor of nitrogen to protein of 6.25 (AOAC Method 979.09), fat content by extraction with petroleum ether under reflux conditions in a Soxhlet (AOAC Method 963.15) and ash by gravimetric method by burning at 550 °C in a furnance (AOAC Method 923.03) (AOAC, 2005). Starch content was analysed by polarimetric method according to the EU regulation no. 152/2009 (European Commission, 2009). Mineral quantification was carried out by atomic absorption spectrophotometer (type AAnalyst 400, Perkin–Elmer, Waltham, MA, USA) after sample digestion with HCl as described by Gupta et al. (2011).

Total dietary fibre (TDF), soluble dietary fibre (SDF), insoluble dietary fibre (IDF) and β-glucan content were determined by enzymatic methods using the assay kits: K-TDFR "Total dietary fibre" (AOAC Method 991.43) and K-BGLU "Mixed-linkage beta-glucan" (AOAC Method 995.16) obtained from Megazyme International Ltd. (Bray, Ireland). Calorie contents were calculated using the following conversion factors: 9 for fat, 4 for carbohydrates, 4 for protein and 2 for fibre following the Commission regulation no.1169/2011 (European Commission, 2011).

2.3. Hydration properties analysis

Water absorption index (WAI) and water solubility index (WSI) were calculated for the oat flour, oat bran and their mixtures, following the method described by Choi et al. (2012). Briefly, 3 g sample and 30 mL water were added in a pre-weighed centrifuge tube and then heated in a water bath at 60 °C for 1 h. After centrifuging (4000 rpm, 15 min), the supernatant was poured in a pre-weighed dish and dried in an oven at 105 °C overnight. The supernatant dry solid weight was used to calculate WSI expressed as percentage of dry solid in the sample weight. The remaining gel in the tube was weighed for WAI measurement, expressed as g gel/g sample weight.

2.4. Thermo-mechanical measurements

The thermo-mechanical properties of oat flour – oat bran blends (using 0%, 30%, 50%, 70%, 100%, w/w, oat bran basis) were studied using a Mixolab analyzer (Chopin Technologies, Villeneuve-la-Garenne, France) with the modified "Chopin+" protocol. The required amount of oat blend was calculated by the Mixolab software (version 3.21) on a 14%-moisture basis and the water required for optimum consistency was added automatically to produce a dough torque of 1.1 ± 0.07 N m.

The dough sample (90 g) was subjected to dual mixing (80 rpm) with a programmed heating–cooling cycle: initial mixing at 30 °C for 8 min, heating to 90 °C for 7 min with 4 °C/min, followed by cooling to 50 °C and then holding at 50 °C for 5 min.

2.5. Cookies preparation

The cookies dough formula consisted of oat flour with replacement by different concentration of oat bran, 0%, 30%, 50%, 70% and 100% (control, 30% OB, 50% OB, 70% OB and 100% OB). The other ingredients were: shortening (26.6%), sugar (21.6%), egg (33.3%), sodium bicarbonate (0.3%), ammonium bicarbonate (0.3%), citric acid (0.6%) and water (33.3%). Fat, sugar and egg were creamed in a planetary mixer (Minneapolis, model PM 7, La Felsinea Srl, Italy) for 5 min at low speed (75 rpm). Then, the OF/OB blend and water containing the dissolved baking powders were added and mixed to form the dough for another 5 min. The dough was kept in the refrigerator for 24 h for better hydration of the bran. Then, cookies of 8 cm length, 2 cm width and 1 cm height were obtained using a dropping machine suitable for production of cookies (Mimac Italia Srl, Piovene Rocchette, model MINIDROPPRO 400-Y7).

The cookies were transferred to a baking tray and baked at 190 °C for 25 min in an oven (Mondial Forni, Verona, Italy). After baking, the cookies were cooled at room temperature (20 °C) and packed in sealed bags before analysis.

2.6. Differential scanning calorimetry (DSC)

A DSC 8000 differential scanning calorimeter (Perkin Elmer, Waltham, MA, USA) calibrated with indium was used to investigate the effect of oat bran on the thermal properties of oat cookies. Oat flour/oat bran mixtures and ground cookies (5 mg) were weighed into 60 μL capacity stainless steel pans and deionized water was added at a ratio of 1:3. Pans were hermetically sealed and left to equilibrate at room temperature overnight. The samples were heated from 20 °C to 120 °C at a rate of 10 °C/min with 20 cm^3/min nitrogen flow rate. An empty pan was used as a reference. Peak temperature (T_P) and enthalpy associated with starch gelatinization were calculated using Pyris Manager software (version 10.1, Perkin Elmer).

Gelatinization degree in the cookies was calculated as (Pauly et al., 2013):

$$\text{Gelatinization degree } (\%) = 100 - [(\Delta H_c/\Delta H_f) \cdot 100],$$

where ΔH_c and ΔH_f are the gelatinization enthalpy of the cookies and oat flour/oat bran mixtures expressed in J/g dm, respectively.

The results are expressed as mean ± standard deviation.

2.7. Environmental scanning electron microscopy (ESEM) study

Microstructure of oat flour/oat bran and ground cookies was examined by Environmental Scanning Electron Microscope (ESEM, XL 30, Philips, Netherlands) equipped with both secondary and back-scattered electrons detector and EDS. The samples were mounted on aluminium stubs using carbon adhesive tapes. The