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Partial replacement of fat with oat and wheat bran gels: Optimization study based on rheological and textural properties

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A B S T R A C T

Wheat and oat brans, by-products of grain processing, were investigated in the form of gels for partial replacement of fat. The objective of this study was to determine the optimal bran concentration, homogenization temperature and time to create bran gel/vegetable fat model systems (BGF model systems) with similar dynamic rheological properties and spreadability to the control fat. The response surface methodology approach based on Derringer's desirability function was applied, and the highest overall desirability was accomplished with the following parameters: 22.0 g/100 g of bran concentration, 11.7 min homogenization time and 83.2 °C homogenization temperature (for the wheat bran) and bran concentration of 22.0 g/100 g, homogenization time of 10.0 min and homogenization temperature of 95.0 °C (for the oat bran). Oat bran required higher homogenization temperature since its structure was mostly built upon starch gelatinization, while wheat bran was capable of making gels under lower temperatures due to fibre cross-linking.

1. Introduction

In recent years, there has been an increasing interest in developing functional food products which have a positive impact on human health and at the same time reduce the risk of many chronic diseases and health conditions. Due to a strong relationship between a high fat intake, and the development of a number of diseases (obesity, diabetes, cancer, high cholesterol levels and coronary heart diseases), many efforts have been made to reduce fat content in food products (Shaltout & Youssef, 2007). This represents a technological challenge due to the fat functionality in food products, affecting desirable characteristic such as: taste, aroma, texture and mouthfeel (Lucca & Tepper, 1994; Omayma & Youssef, 2007; Pareyt et al., 2009; Zoulias, Oreopoulou, & Tzia, 2002).

Many ingredients can serve as fat replacers. They can be categorized as carbohydrate, protein, or fat based fat replacers. The largest group is carbohydrate-based fat replacers, comprising plant polysaccharides including starch and modified starches, maltodextrins and dextrins, polydextrose, cellulose, gums, pectin and inulin (Oreopoulou, 2006). Carbohydrate-based fat replacers act as fat mimetics as they form a gel in the presence of water with the flow pattern similar to the one of lipids (Kalinga & Mishra, 2009). For food technologists, it is especially challenging to produce an ideal fat replacer which possesses lower energy than fat but, at the same time, maintains the sensory characteristics of its full-fat counterpart. Furthermore, it would be an additional advantage if the fat replacer could also improve the food nutritional profile. The significant increase in food product functionality can be achieved by adding dietary fiber-based fat replacers since they can increase the product fiber content, while lowering its fat content.

Recently, there has been growing interest in the valorization of fiber-containing by-products as potential ingredients in the production of fat replacers (Martínez-Cervera, Salvador, Muguerza, Moulay, & Fiszman, 2011). Utilization of these by-products from fruit and vegetable industry has been reported for the peach peels (Grigelmo-Miguel, Carreras-Boladeras, & Martin-Belloso, 2001), orange by-products (Crizel de Moraes, Jablonski, de Oliveira Rios, Rech, & Flôres, 2013), potato pulp (Kaack & Pedersen, 2005), potato peels (Arora & Camire, 1994) and apple pomace (Min, Bea, Lee, Yoo, & Lee, 2010a). Fibers from cereal milling fractions could also be

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used as fat replacers. Warner and Inglett (1997) investigated the influence of partial replacement of fat with corn and oat soluble fiber on sensory and textural characteristics of cookies. Jung, Kim, and Chung (2005) made muffins in which corn bran fiber substituted 10, 30, 50 and 70 g/100 g fat. Inglett, Carriere, Maneepun, and Tungtrakul (2004) used a soluble fiber gel produced from rice bran and barley flour as a fat replacer in Asian foods. These authors studied rheological properties of the obtained gel compared to fat, as well as the effect of the addition of this fat replacer on sensory properties of cookies. Lee and Inglett (2006), in their study, examined the influence of replacing 10, 20 and 30 g/100 g of shortenings with jet-cooked oat bran on the rheological behavior of dough, as well as the physical properties of cookies. The effect of replacing shortenings with β-glucan concentrates (BGC), prepared from barley and oats, on rheological and physical properties of cake batter was investigated by Kalinga and Mishra (2009) showing that the addition of BGC increased consistency, flow behavior indices, storage and loss moduli of batter. In all above mentioned studies commercially available fiber-based fat replacers have been used, while our intention was to investigate the possibility of grain processing by-products (wheat and oat brans) to act as fat replacers in their native form. Literature data have shown that wheat bran contains 36.5–52.4 g/100 g of total dietary fiber, while oat bran contains 18.1–25.2 g/100 g of total dietary fiber, from which 35.0–48.4 g/100 g and 14.5–20.2 g/100 g are insoluble dietary fiber, and 1.5–4.0 g/100 g and 3.6–5 g/100 g are soluble dietary fiber, respectively (Vitaglione, Napolitano, & Fogliano, 2008). Besides increasing the content of total dietary fiber in food products, addition of cereal bran can also contribute to the enrichment of food with bioactive compounds such as phenolic acids, flavonoids, oligosaccharides, proteins, folates, sterols, vitamins and minerals (Patel, 2015).

The aim of this study was to investigate the possibility of wheat and oat bran gels to mimic vegetable fat dynamic rheological properties and spreadability. The response surface methodology approach based on Box-Behnken's fractional factorial design was performed to find gels preparation conditions (bran concentration, homogenization temperature and time) to obtain optimal bran gels for partial fat replacement. Two main goals of optimization study were: a) to create bran gel/vegetable fat model systems (BGF model systems) with similar textural and rheological properties to the control fat and b) to achieve maximal enhancement of mixture nutritional and functional properties.

2. Materials and methods

2.1. Materials

Commercially available wheat and oat brans obtained from “Biouna” (Novi Sad, Serbia) were ground using a laboratory cross beater mill (Retsch SK1, Retsch GmbH, Haan, Germany) equipped with 0.8 mm sieve. Commercially available vegetable fat (AP 36/38 HF) obtained from “Puratos” (Belgrade, Serbia) was used as the control sample, as well as for preparation of bran gel/vegetable fat (BGF) model systems.

2.2. Chemical properties of bran samples

Proximate composition of brans was determined by standard methods of analysis (AOAC, 2000) for protein (Method No. 950.36), fat (Method No. 935.38), reducing sugar (Method No. 975.14), ash (Method No. 930.22), cellulose (Method No. 950.37), total and insoluble dietary fibre (Method No. 991.43) and water content (Method No. 926.5) determination. Starch content was determined by hydrochloric acid dissolution according to the ICC Standard (ICC Standard No. 123/1, 1994).

2.3. Wheat and oat bran pasting properties

Pasting behavior of tested bran samples was investigated using a HAAKE MARS-Modular Advanced Rheometer Systems (Thermo Scientific, Karlsruhe, Germany). The measuring geometry consisted of measuring cup Z40 (43.4 mm diameter, 8 mm gap), FL2B paddle-shaped rotor with 2 blades and solvent trap Z40 DIN for preventing moisture evaporation. The bran suspension was prepared with 10.7 g of bran (calculated on 14 g/100 g moisture basis) and 60 mL of distilled water to obtain the same flour-water ratio as in the standard Amylograph method. The measurements were conducted according to the modified procedure described by Pojić, Hadnađev, and Dapčević Hadnađev (2013). The procedure comprised the simulation of Amylograph test with a heating rate of 1.5 K/min from 50 to 95 °C and maintaining the temperature of 95 °C for a period of 600 s, cooling down to 50 °C and maintaining the temperature of 50 °C for a period of 600 s. A shear rate of 10/s was applied, which corresponded to 95 rpm.

2.4. Preparation of bran gels

The wheat and oat brans' powders were dispersed in distilled water (pH was adjusted between 9.0 and 10.0) under high shear of 6000 rpm by a homogenizer with a dispersing tool S25N–18G (Ultraturax T-25, IKA, Werke GmbH & Co., Staufen, Germany). The bran gels were prepared using hydro-thermal treatment accompanied by mechanical shear stress, while bran concentration and conditions of hydro-thermal treatment (homogenization temperature and time) were varied according to Table 1. Preparation of bran gels was conducted in two replicates (two separate batches for each combination of experimental factors were made).

2.5. Preparation of bran gel/vegetable fat model systems

To determine the effect of fat replacement with fibre gel on the rheological and textural properties, wheat/oat bran gels prepared according to Table 1 were cooled down, mixed with vegetable fat in the ratio of 1:1 (w/w) and homogenized using a disperser Ultraturrax T-25 in a water bath at 25 °C. Applied mixing speed was 6000 rpm during 300 s.

Table 1
Combinations of experimental factors, according to Box-Behnken fractional factorial design.

Run number	Bran concentration, C (g/100 g)	Homogenization time, t (min)	Homogenization temperature, T (°C)
1	18	10	85
2	22	10	85
3	18	30	85
4	22	30	85
5	18	20	75
6	22	20	75
7	18	20	95
8	22	20	95
9	20	10	75
10	20	30	75
11	20	10	95
12	20	30	95
13	20	20	85
14	20	20	85
15	20	20	85