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Coffee silverskin as a source of dietary fiber in bread-making: Optimization of chemical treatment using response surface methodology

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ABSTRACT

Nowadays, there is a growing demand from consumers for baked products with lower caloric density and higher levels of dietary fiber. In the present study, the response surface methodology was used to determine the optimum treatment of coffee silverskin (CS) with alkaline hydrogen peroxide that gave the best quality, shelf life, sensory and image properties for Barbari flat bread. Contact time, solution portion and particle size were considered components of the chemical treatment. The most compatible model among mean, linear and quadratic expressions was fitted to each response and the regression coefficients were determined using least square method. The optimum condition was found to be a chemical process containing mixing time of 1 h, solution portion of 4.77 and particle size of 116.41 μm when desirability function method was applied. There was a good agreement between the experimental data and their predicted counterparts. Results showed that alkaline hydrogen peroxide CS might be useful as an ingredient for reducing caloric density and increasing dietary fiber content of bread.

1. Introduction

Many forms of dietary fiber have been used in bread-making and other cereal-based products. Among these dietary fiber forms are wheat fiber, whole grain rye, psyllium husk fiber, flaxseed and soy hull (Glitsø & Bach Knudsen, 1999; Park, Seib, & Chung, 1997; Pohjanheimo, Hakala, Tahvonen, Salminen, & Kallio, 2006; Riaz, 2001). Except for these dietary fiber sources, there are some dietary sources that are not used in bread-making such as coffee silverskin. Coffee is a major food commodity; therefore, coffee byproducts are sufficiently available. The coffee silverskin (CS) is a tegument of coffee beans that constitutes a byproduct of the roasting procedure. CS is therefore obtained in coffee roasting plants located in the Western countries and presently used as combustible or fertilizer (Saenger, Hartge, Werther, Ogada, & Siagi, 2001). Different studies have shown the healthy properties of coffee brews: the antioxidant capacity (Borrelli, Visconti, Mennella, Anese, & Fogliano, 2002; Nicoli, Anese, Parpinel, Franceschi, & Lerici, 1997), the antibacterial and *ex vivo* protective activities (Daglia, Papetti, Dacarro, & Gazzani, 1998; Daglia, Papetti, Gregotti, Bertè, & Gazzani, 2000), the anticarcinogenic effects (Abraham & Singh, 1999), and the ability to increase plasma total glutathione (Esposito et al., 2003). As CS is the outer layer of the roasted coffee beans, it is conceivable that some of the properties described for coffee brews are maintained also in CS. Due to its high fiber content, it becomes an important ingredient that can be incorporated in several food formulations. However, some structural modifications would be necessary since the addition of this material has negative effects on the final products, including gritty texture and poor appearance (Borrelli, Esposito, Napolitano, Ritieni, & Fogliano, 2004).

These deleterious effects can be due to the gluten dilution, low tendency of this material to hydration and subsequently low swollen capacity. These rigid and incompletely hydrated particles function as inclusions, weakening dough by cutting gluten strands (Gould, Jasberg, Dexter et al., 1989; Park et al., 1997). The low hydration capacity of this lignocellulosic residue is resulted, fundamentally, from the protective association of lignin and hemicellulose that blocks the entrance of water, and the degree of crystallinity within the cellulose polymer itself (Gould, 1985). The physical properties of fiber are altered substantially by treatment with alkaline hydrogen peroxide (AHP), which acts as a solubilizing part of the lignin and reducing cellulose crystallinity through rupture of the hydrogen bonding between and into chains, producing a material with more open internal structure. This causes an increase in the water retention capacity and swelling of fiber, getting better, therefore, sensory characteristics of product (Artz, Warren, & Villota, 1990; Gould, 1985; Larrea, Grossmann, Beléia, & Tavares, 1997).

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To the best of our knowledge, there are no reports on the use of CS as a source of dietary fiber in bread-making. Thus, the present study was designed: (a) to examine the effects of chemical treatment conditions i.e. portion of CS to alkaline hydrogen peroxide solution, mixing time and particle size of coffee silverskin on fiber characteristics and Barbari flat bread performance; (b) to determine the optimum conditions for chemical treatment of CS; (c) to check the validity of response surface methodology (RSM) to analyze the synergistic and/or antagonistic effects of alkaline hydrogen peroxide treatment on the quality, shelf life and sensory properties; and (d) to obtain the relationship between quality, shelf life, sensory and image parameters.

2. Materials and methods

2.1. Materials

Commercial *Triticum aestivum* wheat flour (locally named Setareh) was procured from the AceeArd Co., Khorasan, Iran. Dried active yeast was obtained from Fariman Co., Khorasan, Iran. Shortening was provided by Jahan Company (Tehran, Iran). Coffee silverskin from variety of arabica, Brazil used for investigation was provided by MultiCafé company, located in Khorasan, Iran. All other chemicals, reagents and solvents were of analytical grade.

2.2. Methods

2.2.1. Physicochemical characteristics of wheat flour and row CS

Moisture (44-16 A), protein (46-13), ash (08-07), fat (30-10), wet gluten (38-11), falling number (56-81), total dietary fiber and soluble and insoluble fractions (32-07) were determined according to standard AACC (2000) methods. Carbohydrate content was estimated by difference. Three replications were taken for each characteristic.

2.2.2. Box–Behnken design

A Box–Behnken design was constructed using the software Design Expert Version 6.0.10 (Stat-Ease Corporation, Minneapolis, MN, USA) and was used for sampling of different combination of AHP-treatment factors i.e. portion of CS to alkaline hydrogen peroxide solution, mixing time and particle size (Table 1). The design consists of 17 sets of test conditions where three levels were attributed to each factor at high, central, and low levels, with additional four replicated center points. Maximum and minimum treatment levels were chosen by carrying out preliminary screening tests and according to the literature reports and economic aspects.

Table 1
Variables and levels used in Box–Behnken design for alkaline hydrogen peroxide treatment.

Trial	Variable codes			Actual values		
	Time	Solution portion	Particle size	Time (h)	Solution portion	Particle size (μm)
1	−1	−1	0	1	1	75
2	1	−1	0	12	1	75
3	−1	1	0	1	5	75
4	1	1	0	12	5	75
5	−1	0	−1	1	3	4
6	1	0	−1	12	3	4
7	−1	0	1	1	3	150
8	1	0	1	12	3	150
9	0	−1	−1	6.5	1	4
10	0	1	−1	6.5	5	4
11	0	−1	1	6.5	1	150
12	0	1	1	6.5	5	150
13	0	0	0	6.5	3	75
14	0	0	0	6.5	3	75
15	0	0	0	6.5	3	75
16	0	0	0	6.5	3	75
17	0	0	0	6.5	3	75

2.2.3. Alkaline hydrogen peroxide treatment

CS was washed in tap water, and placed in an oven at 60 °C for 24 h for complete drying. It was ground and separated according to particle size (4–150 μm) using a sieve shaker. A sample of CS was treated with dilute hydrogen peroxide solution with a concentration of 1 mL/L at pH = 11.5 that regulated by adding 1 mol equi/L NaOH. The portion of CS to AHP was varied from 1:3 to 1:5 according to Table 1. After mixing the two components, the solution was stirred with a vortex mixer for 1–12 h. Then, neutralization was done with 0.1 mol equi/L HCl, the material was collected by filtration, washed with water, and dried in a forced air oven at 60 °C for 8 h.

2.2.4. Physical characteristics of AHP-treated CS

Color differences among treatments were determined using a flatbed scanner and according to the section of image analysis. The average values of L^*, a^* and b^* colors describing the appearance of CS were obtained from all 17 AHP-treated samples.

Water activity (a_w) was measured at 25 °C with a water activity meter (Novasina ms1-aw, Axair Ltd., Pfaffikon, Switzerland) after calibration with standard salt (AOAC, 1995). The experimental error in a_w determination is 0.005 a_w units.

The water holding capacity (WHC) of CS was measured by a modified procedure described by Ang (1991). Sample (1 g) mixed with 15 mL distilled water in a 30-mL centrifuge tube. Sample after 10 min stand, centrifuged at 2000×*g* for 15 min by Sigma 3-30k, made in Germany. The excess water was then removed by allowing the wet sample to drain on a fine-meshed wire screen. A portion of the wet sample on the screen was carefully removed and weighed. The result was showed by gram of water and according to equation (1)

$$\mathrm{WHC} = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}}. \quad (1)$$

Oil holding capacity (OHC) was similarly measured as water holding capacity except sunflower oil used instead of distilled water. OHC was expressed as gram of oil and according to equation (2)

$$\mathrm{OHC} = \frac{\text{pellet weight} - \text{dry weight}}{\text{dry weight}}. \quad (2)$$

2.2.5. Bread-making and evaluation of breads

The bread formula used for this kind of bread consisted of flour; compressed yeast (2 g/100 g flour); salt (2 g/100 g flour); sugar (1 g/100 g flour); shortening (1 g/100 g flour); water (based on water absorption at 400 BU). This consistency was found by experimentation to give the most reliable prediction of baking absorption (Maleki, Vetter, & Hoover, 1981) when mixed with the dry ingredients at different speeds. CS was used at 5 g/100 g wheat flour according to the literature reports and economic aspects. CS samples were mixed in the mixer (Electronic Stand Mixer, Hügel, Neuss, Germany) for 10 min at 100 rpm with the other ingredients of the bread formula. A baking technique, similar in principle to that of commercial procedure, was used for baking experimental loaves (15 × 25 × 2.5 cm) having almost equal volumes. In this procedure, the ingredients were mixed for 10 min to optimum dough development obtained by farinograph. The dough samples were fermented in sealed steel containers at 30 °C and 75–85% relative humidity for 60 min, and then divided into 200 g pieces and