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Microstructural, physicochemical, antioxidant, textural and quality characteristics of wheat muffins as influenced by partial replacement with ground flaxseed

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ABSTRACT

This study investigated the effects of flaxseed powder (FP) on muffin quality parameters by the progressive replacement of wheat flour (WF) in the muffin formulation with FP from three different flaxseed cultivars. The antioxidant potential, physicochemical, microstructural and textural properties of muffins and the pasting properties of the flour blends were analysed. Addition of increasing amount of FP in the blends improved the nutritional characteristics but decreased the muffin volume; the muffin crumb color became darker and hardened in texture. The pasting characteristics of wheat flour was influenced by FP incorporation with a decrease in peak, final and setback viscosity values with increasing amount of FP addition being observed. Flaxseed was found to be rich in antioxidant potential as evident from its high DPPH scavenging activity, total phenolic content and reducing power in comparison to WF. The microstructure of muffin crumb showed that degree of disruption of protein matrix increased with an increase in the level of FP. Among different cultivars, "LC-2023" cv. exhibited the highest sensory scores and can be recommended as potential cultivar for its health benefits. Supplementation of wheat muffins with 10% FP is a successful approach to enrich it with nutrients and increase its antioxidant potential.

1. Introduction

Flaxseed (*Linum usitatissimum*) is a food and fibre crop that is grown in cooler regions of the world (Reddy, Jayathilakan, Pandey, & Radhakrishna, 2012). Flaxseed has an excellent nutritional profile, and has, therefore, become an attractive ingredient in the diets formulated for specific health benefits (Kaur, Kaur, & Gill, 2017). Flaxseed is rich in several nutrients such as lignans, fiber, fat and protein (Shearer & Davies, 2005) and has gained attention as a functional food because of its potential to reduce the risk of certain chronic diseases (Ramcharitar, Badrie, Mattfeldt-Beman, Matsuo, & Ridley, 2005). Awareness about therapeutic nutrition has driven consumer demand for health and functional foods with higher contents of minerals, fiber and antioxidants (Goswami, Gupta, Mridula, Sharma, & Tyagi, 2015). The beneficial health-related effect of flaxseed makes it suitable as an important ingredient in functional foods which are consumed as part of a daily diet (Aliani, Ryland, & Pierce, 2011). The popularity of bakery products such as bread, muffins, biscuits, cakes and pastries is increasing tremendously (Goswami et al., 2015). The increasing importance of bakery products in today's eating habits means that these food products are being readily accepted by consumers and thus can serve as vehicles for important nutrients (Alpaslan & Hayta, 2006). Flaxseed has been promoted as egg replacer in home-baked goods, creating the option of vegan products (Shearer & Davies, 2005). Ground flaxseed (5–15%) can be added to almost any baked product conferring a nutty flavor to them (Chetana, Sudha, Begum, & Ramasarma 2010). The U.S. Food and Drug Administration have suggested the use of flaxseed up to 12% in foods (Ramcharitar et al., 2005). Muffins are a sweet, high calorie baked product appreciated among the consumers of all age groups due to its soft texture and good taste (Goswami et al., 2015), ready-to-eat nature, their availability in different varieties and affordable cost (Mildner-Szkudlarz et al., 2016). In addition to it, muffin is a popular breakfast or afternoon snack food, which is sold in many bakeries (Matos, Sanz, & Rosell, 2014). Previous studies have reported effect of flaxseed addition on the flavor profile and other quality characteristics of different baked products such as muffins, cookies, bagels and snack bars (Aliani et al., 2011; Chetana, Begum, & Ramasarma, 2010; Kaur et al., 2017; Ramcharitar et al., 2005; Shearer & Davies, 2005). Flaxseed meal added to banana nut muffins had higher acceptability scores for color, flavor, shape and texture than control muffins (Alpers & Sawyer-Morse, 1996). The present study therefore focussed on utilization of three different flaxseed cultivars at varying levels (10%, 20%, 30% and 40%) as a

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functional ingredient in muffins. Also, the effect of flaxseed addition on the rheological, microstructural, and antioxidant properties, and quality characteristics of muffins was studied aiming at selection of a cultivar which would not only enrich the muffins with nutrients but also possess the best measured properties.

2. Materials and methods

2.1. Materials

Three Indian flaxseed cultivars namely: Jawahar-27 (from Madhya Pradesh), LC-2023 (from PAU, Ludhiana) and Jeevan (from CSKV, Palampur, Himachal Pradesh) were procured. The grains were cleaned, ground in Newport Super mill (Australia) to pass through 60 BSS (250 µm) sieve to obtain flaxseed powder (FP) and stored in a refrigerator till further analysed. Besides the control sample (100% wheat flour) various blends of composite flour mixes (90WF:10FP, 80WF:20FP, 70WF:30FP and 60WF:40FP) were prepared by replacing wheat flour (WF) with FP and stored in air tight containers.

All chemicals were of analytical grade. Standard gallic acid and 2, 2-diphenyl-1-picrylhydrazyl (DPPH) were procured from Sigma-Aldrich (Steinheim, Germany), whereas the rest of chemicals were from Loba Chemie, Mumbai, India.

2.2. Preparation of muffins

Muffins were prepared both from wheat flour and composite flour mixes with the modified method as described by Nicol (1995). The ingredients used in the preparation of the muffin were wheat flour/composite flour mix (100 g), fat (50 g), sugar (50 g), eggs (50 g), milk (50 g), baking powder (3.33 g), and salt (0.4 g). Muffin formulation containing only WF was taken as the control sample. Sugar, eggs, fat and milk were blended for 2 min using a three pin mixer (Morse ED series, USA). Wheat flour, baking powder and salt were then added and mixed for 20 s. The batter (50 g) was poured into a muffin cup and baked at 200 °C for 25 min in a preheated oven.

2.3. Proximate composition

The samples were estimated for their moisture, ash, fat, protein (N × 6.25) and crude fiber content by using the standard methods of analysis (AOAC, 1984).

2.4. Antioxidant properties

2.4.1. Extraction of bioactive compounds

The muffin samples were ground in an electric grinder to obtain a fine powder (110–120 mesh). The samples were defatted with hexane (1:5 w/v, 5 min thrice), dried at 40 °C for 24 h and further extracted in serological water bath (Macro scientific works Pvt Ltd, New Delhi, India) with methanol (70%, 1:10 w/v) at room temperature for 60 min. Samples were filtered using Whatman filter paper (No. 1) and were stored at 4 °C for further analysis.

2.4.2. DPPH (2,2- Diphenyl–1′ picrylhydrazyl) radical scavenging assay

The DPPH radical scavenging activity was measured by following the method as described by Brand-Williams, Cuvelier, and Berset (1995). Briefly to 100 µL of extract, 3.9 mL of DPPH solution (6×10^{-5} mol/L) was added. Absorbance of the extract (A) at 515 nm was read at 0 and 30 min using methanol as blank. Percent (%) DPPH scavenging activity was calculated as:

$$\text{DPPH scavenging activity (\%)} = (1 - (\text{A of sample}_{t=30} / \text{A of control}_{t=0})) \times 100$$

2.4.3. Total phenolic content (TPC)

TPC of different extracts was determined by the method as described by Gao, Wang, Oomah, and Mazza (2002). An aliquot of extract (200 µL) was mixed with 1.5 mL freshly diluted (10 fold) Folin–Ciocalteu reagent. After equilibration for 5 min, the extract was then mixed with 1.5 mL of sodium carbonate solution (60 g/L), incubated for 90 min at room temperature. Absorbance of the mixture was read at 725 nm and the results were expressed as µg of gallic acid equivalents (GAE) per gram of sample.

2.4.4. Metal chelating activity

Metal chelating activity was estimated by the method described by Dinis, Madeira, and Almeidam (1994). To the extract (0.5 mL) was added 50 µL of ferrous chloride (2 mM/L) followed by addition of 1.6 mL of 80% methanol. The reaction was then initiated by adding 5 mM/L ferrozine (100 µL) after 5 min. The mixture was vortexed and incubated at ambient temperature (25 °C) for 10 min. The absorbance of the mixture was measured at 562 nm and the metal chelating activity was calculated as follows:

$$\text{Metal chelating activity (\%)} = \{1 - (\text{Absorbance of sample} / \text{Absorbance of control})\} \times 100$$

2.4.5. Reducing power

Reducing power of the extracts was measured by the method given by Zhao et al. (2008). To an aliquot of extract (100 µL), phosphate buffer (2.5 mL, 0.2 mol/L, and pH 6.6) and 2.5 mL potassium ferricyanide (1%) were added followed by incubation at 50 °C. Trichloroacetic acid solution (10%) was then added to the mixture and centrifuged at 10,000 g for 10 min. 2.5 mL of supernatant was taken and was mixed with 0.5 mL of ferric chloride (0.1%) and 2.5 mL of deionized water. The absorbance of the solution was measured at 700 nm and the results were reported as µmol ascorbic acid equivalents/g of sample.

2.5. Pasting properties of the flour blends

The pasting properties were measured using a starch cell of Modular Compact Rheometer (Anton Paar MCR-52, Austria) by the method as described by Kaur and Singh (2016). Viscosity profiles of samples were recorded by mixing 3.5 g flour sample with 25 mL distilled water in an aluminium canister. Parameters recorded were peak, trough, breakdown, final, setback viscosities and pasting temperature.

2.6. Physical properties of muffins

Muffins were cooled for 2 h after removing from oven at room temperature on a wire grid and weighed. Muffin height was measured from the highest part of the muffin to the bottom part using vernier calliper. Muffin volume was determined by the rapeseed displacement method. Specific volumes were calculated by dividing volume by weight and expressing the results as milligram per gram.

2.7. Textural analysis of muffins

The textural characteristics of the muffins were determined using texture profile analysis with a CTA-XT2i texture analyzer (Stable Micro Systems, Surrey, UK). The instrument was equipped with the 5 kg load cell. Square-shaped pieces of muffins measuring 5 cm on all sides and with a sample thickness of 2.5 cm were compressed twice to 50% of their original height with cylindrical probe of 75 mm diameter. The test speed was 1 mm/s and there was a 10s interval between the two compression cycles. The textural parameters viz. hardness (N), cohesiveness, springiness and chewiness (product of hardness × cohesiveness × springiness, N) of the muffin samples were