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Functional characterization of extruded rice noodles with corn bran: Xanthophyll content and rheology

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ABSTRACT

The rheological changes in rice noodles by the substitution of corn bran and the effect of temperature on the xanthophyll content (lutein and zeaxanthin) of the corn bran-rice flour noodles were evaluated. The use of corn bran increased the water holding capacity of rice flour at room temperature while the opposite results were observed after heating. The pasting parameters of rice flour-corn bran mixture were reduced with increasing levels of corn bran and the mixture paste exhibited more dominant liquid-like behavior. The noodles containing corn bran exhibited lower expansion ratio and softer textural properties. The levels of lutein and zeaxanthin in raw corn bran were 336.9 and 123.1 μg/100 g, respectively and were significantly reduced ($P < 0.05$) by heating. While lutein and zeaxanthin were not detected in the control noodles without corn bran, their levels in corn bran-incorporated noodles ranged from 56.2 to 137.3 μg/100 g and from 37.9 to 61.9 μg/100 g, respectively and were significantly reduced by 37.7–45.4% ($P < 0.05$) after cooking. Thus, the heat-labile characteristics of two xanthophylls were clearly observed. This study provides useful information on the processing performance and xanthophyll content of corn bran, possibly extending its use in a wider variety of foods.

1. Introduction

Corn is one of the most widely cultivated cereals in the world along with wheat and rice. The world production of corn is estimated to expand by 28% from 31 billion bushels in 2011–2012 to 39 billion bushels in 2022 (Taylor and Koo, 2013). Thus, the global market of corn continues to increase around the world. However, the increasing use of corn leads to the production of a large amount of corn bran that is a byproduct from the corn milling industry (Wang et al., 2013). Corn bran is generally used for animal feed but is sometimes treated as waste and causes disposal problems (Zhang and Whistler, 2004). Recently, there have been scientific and industrial interests in searching for an alternative way to increase the economic value of corn bran (Rose et al., 2010). Although corn bran is still underutilized, it has been receiving great attention as a source of dietary fiber from a food science point of view. In preceding studies, corn bran was incorporated into the formulations of several wheat-based food products for fiber fortification such as snacks (Mendonça et al., 2000), baked goods (Artz et al., 1990; Willis et al., 2009), and noodles (Sharma et al., 2012). There is however an apparent lack of fundamental information on the physicochemical or rheological role of corn bran in a wider variety of food products derived from other cereal sources. Furthermore, the studies on the bioactive components of corn bran other than dietary fibers are very limited.

Lutein and zeaxanthin that belong to the xanthophyll family of carotenoids are the two major pigments in the macular region of the retina (Krinsky et al., 2003). There exist structural differences between lutein and zeaxanthin – lutein contains a β-ionone ring and a ε-ionone ring while zeaxanthin has two β-ionone rings. It is reported that they play significant roles in promoting the health of eyes, reducing the risk of age-related cataract (Abdel-Aal et al., 2013). However, since they must be provided from the diet, their levels in the human body are entirely dependent on dietary intake (Ishida and Chapman, 2009). Lutein and zeaxanthin are naturally abundant in green leafy vegetables (e.g., kale, spinach, and broccoli) and egg yolk. Also, they are found in corn and their products. It is reported that 151–368, 402–762, 232–596, 218–443, and 1200–1470 μg of lutein are found per 100 g of canned corn, corn meal, corn flour, cornflake, and fresh corn, respectively (Calvo, 2005; De Oliveira and Rodriguez-Amaya, 2007). However, there are few studies on the levels of lutein and zeaxanthin in corn bran

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and its food products. Moreover, the response of the two xanthophylls to heating in a real food system has not been found yet to our best knowledge. It is necessary to investigate their thermal-stability under different heating conditions for practical food applications.

In this study, corn bran was incorporated into the formulation of extruded rice noodles and their functional characteristics were evaluated in terms of xanthophyll (lutein and zeaxanthin) contents and rheological properties.

2. Experimental

2.1. Materials

Corn bran was supplied by Samyang Genex Co. (Incheon, Korea) and the contents of moisture, protein, fat, and ash in the corn bran were determined to be 1.94%, 8.62%, 5.65%, and 0.91%, respectively. The corn bran was rich in dietary fibers which were composed of 66.49% insoluble and 0.04% soluble fibers. Rice flour was provided by Nongshim flour mills Co., Ltd. (Chungcheongnam-do, Korea). Xanthophyll standards (≥95% purity, analytical grade) were purchased from Extrasynthese (Genay, France). HPLC grade methanol and methyl-tert-butyl ether (MTBE) were purchased from JT Baker Chemical Co. (Avantor Performance Materials, Center Valley, PA, USA). All other chemicals used in this study were of analytical grade.

2.2. Preparation of corn bran powder

Corn bran was ground by an ultra-fine mill (ECO-10, ECO D&S, Gimpo-si, Korea) and sieved through a 100 mesh screen. The ground corn bran was mixed with distilled water (10%, w/v) and agitated at room temperature for 1 h. After filtration with miracloth (Merck KGaA, Darmstadt, Germany), the separated residue was freeze-dried.

2.3. Sample preparation

Extruded rice noodles were prepared by using a twin-screw extruder (Technovel Co., Osaka, Japan) where there was an orifice (2.4 mm diameter) on the die (Baek et al., 2013). Rice flour was equilibrated to a 35% moisture level which was determined from preliminary experiments. For rice flour-corn bran blends, corn bran was incorporated into the rice flour at 20, 40, and 60% by weight. As described in Table 1, the extruder screw consisted of forward pitch screw elements and kneading blocks that gave an overall length-to-diameter (*L*/*D*) ratio of 30:1. The barrel screw speed was 200 rpm and the feed rate was 287 g/h. Barrel temperature was maintained at 80 °C by circulating cooling water. The extruded noodle strips were dried at 40 °C for 1 h and stored in a plastic bag for succeeding analysis. The noodle samples (5 g) were immersed in boiling water (150 mL) for 5 min and then drained in a strainer for 5 min, followed by tensile property measurement. Also, the noodle strands before and after cooking were freeze-dried and ground to pass through a 100 mesh sieve for xanthophyll analysis by HPLC.

Table 1
Screw configuration for rice noodle extrusion.

Type of screw element	Screw pitch (mm)	Screw length (mm)	No. of screw elements	No. of discs/ Staggering angle (°)
[a]F	8	8	2	
F	12	12	3	
[b]K	12	12	1	5/45
F	8	8	1	
F	12	12	1	
[c]FT	18	18	1	
K	12	12	2	5/45
F	8	8	2	
F	12	12	1	
F	18	18	1	
K	12	12	2	5/45
F	8	8	1	
F	12	12	4	
F	18	18	3	
[d]FD	18	18	2	
F	8	8	1	

[a] F – Forward pitch.
[b] K – Kneading block.
[c] FT : Taper feeding element.
[d] FD : Deep feeding element.

2.4. Thermal stability analysis of xanthophylls in corn bran

Corn bran was subjected to different heating conditions for evaluating the thermal stability of xanthophyll compounds (lutein and zeaxanthin) in corn bran. Corn bran powder was suspended in distilled water at a ratio of 10% (w/v) and the suspension was agitated at different temperatures (30, 60, and 90 °C) for 30 min. In addition, it was placed at 90 °C for different times (0, 5, 10, 20, 30, and 60 min). After heating, the samples were centrifuged at 4,500 × *g* for 15 min and the residues were freeze-dried, followed by HPLC analysis.

2.5. Carotenoid extraction

Sample powder (0.1 g) was treated with 25 mL of 70% ethanol and butylated-hydroxy-toluene (10 mg) was added to prevent the oxidation of carotenoids. The sample was agitated for 4 h and centrifuged at 4,500 × *g* (4 °C, 15 min). The supernatant was collected and the residue was re-extracted with 70% ethanol two more times in the same way. After the ethanolic extracts were combined, they were evaporated by using a vacuum rotary evaporator (N-1110, Tokyo Rikakikai Co., Ltd., Tokyo, Japan) at 40 °C (Moros et al., 2002).

2.6. HPLC analysis

In accordance to the method of Liu et al. (2007) with slight modifications, the levels of lutein and zeaxanthin in corn bran and noodles were quantitatively measured using an Agilent 1200 series HPLC (Santa Clara, CA, USA) with a UV detector (G1315D, Agilent Technologies, Waldbronn, Germany) at 445 nm and a C30 column (CT99S05-2546WT, YMC Co. Ltd., Kyoto, Japan). The mobile phase for the HPLC analysis consisted of methanol/MTBE/water (81:15:4, v/v/v) (solvent A) and methanol/MTBE (9:91, v/v) (solvent B). The extract sample was re-dissolved in 2 mL of mobile phase A and filtered with a 0.45 μm syringe filter (Pall, New York, USA). A linear gradient of solvents A and B was applied from 100% A to 0% B to 50% A and 50% B for 45 min, followed by 100% B within 15 min. The flow rate was 1.0 mL/min and the column temperature was set at 25 °C.

2.7. Measurement of water holding capacity

The water holding capacity of corn bran-rice flour blend was determined at two different temperatures (25 and 100 °C) (Lee and Inglett, 2007). Rice flour was substituted with corn bran at 0, 20, 40, and 60% (w/w) and a sample of 0.1 g from each blend was mixed with 30 mL of deionized water. The suspension was vigorously agitated at two different temperatures (25 and 100 °C) for 30 min, followed by centrifugation at 15,000 × *g* for 30 min. The supernatant was decanted and the weight of residue was measured. Water