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Wheat fiber colored with a safflower (*Carthamus tinctorius* L.) red pigment as a natural colorant and antioxidant in cooked sausages

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ABSTRACT

This study was conducted to evaluate the effects of nitrite and wheat fiber (WFC) colored with a safflower (*Carthamus tinctorius* L.) red pigment on the color characteristics and lipid oxidation of cooked sausages. The safflower red pigment (carthamin) was extracted at alkali condition, and wheat fiber was colored with the extracted safflower red pigment. Total six cooked sausage treatments were prepared with two nitrite levels (0 and 120 ppm) and three WFC levels (0, 1, and 2%). As the WFC level was increased, redness of cooked sausages increased, regardless of presence/absence of nitrite. Carthamin contained in WFC could promote a reaction and/or decomposition of nitrite, resulting in increased nitrosoheme pigment and decreased residual nitrite. In addition, WFC inhibited lipid oxidation of cooked sausages. Consequently, the addition of WFC resulted in positive effects on color formation, residual nitrite, and lipid oxidation, as well as the improvement cooking yield of cooked sausages. Therefore our result suggested that WFC could be possible to partially replace nitrite and coloring of dietary fiber with natural pigments is a useful technique to expand the purposeful use of dietary fiber.

1. Introduction

In modern food industry, the importance of dietary fiber has been emphasized due to its technological properties to improve the processing quality of beverages, dairy, and meat products, as well as primarily nutritional and physiological benefits to human health (Elleuch et al., 2011). For these reasons, dietary fiber produced from various natural plant sources has been extensively used to improve cooking yield and to modify texture of meat products. The technological properties of dietary fiber depend on the proportion of insoluble and soluble fiber contents. The insoluble fiber (mainly cellulose), which possesses water and fat binding abilities, is abundant in cereal by-products. In processed meat products, rice bran (Choi et al., 2010), rye bran (Petersson, Godard, Eliasson, & Tornberg, 2014), and wheat bran (Jiménez Comenero, Ayo, & Carballo, 2005; Mansour & Khalil, 1997) have been utilized as a fiber-rich non-meat ingredient. Particularly, wheat fiber, which contains rich amounts of cellulose (approximately 75%), has been considered as an excellent extender, fat replacer, texture modifier, and salt replacer in several processed meat products (Jiménez Comenero et al., 2005; Mansour & Khalil, 1997; Sarıçoban, Yılmaz, & Karakaya, 2009; Yılmaz, 2005). Despite such advantages, however, there have been no reports on the notable effect of dietary fiber from wheat bran and flour on color characteristics of meat products.

Most consumers have preferred the intense pink-reddish color of cured meat products. Nitrite and nitrate have been generally used to form the preferred cured meat color by the formation of nitrosomyoglobin ($MbFe^{2+}NO$). However, the reaction of residual nitrite and secondary amine in a stomach can form carcinogenic nitrosamines. Thus, the development of substitutes has been required and attempted, which should fulfill the functionalities of nitrite, e.g. the prevention of oxidation and warmed over flavor, the growth inhibitory of microorganisms, the improvement of sensory satisfaction as well as color development (Eyiler & Oztan, 2011).

Safflower (*Carthamus tinctorius* L.), which is an annual plant of chrysanthemum, contains yellow and red pigments (carthamin) in its petal. The safflower pigments have been traditionally used in cloth dyeing and natural cosmetic material as early as 4500 BC. Currently, the yellow pigment (water-soluble) are utilized as a

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natural yellow food colorant in rice, bread, candy, jelly, and beverage, whereas the red pigment (water-insoluble) has been mainly used as a cloth dyeing (Yoon et al., 2003; Yoon, Hahn, & Yoon, 2001;). Although carthamin can be also used in food products including chocolates in China and Japan, however, there is a limit of the utilization of carthamin as a food colorant due to its low solubility and stability in water (Ekin, 2005; Emongor, 2010). According to Saito (1990), the major principle of the cloth dyeing using the red pigment is based on the specific and strong adsorbability of primary alcoholic hydroxyl group on glucose in carthamin to cellulose. Yoon et al. (2001) reported the stability of safflower red pigments binding polysaccharides against pH, temperature, and light alterations, and they suggested the potential application of safflower red pigments as a natural food colorant. In addition, recent studies have reported that safflower petals contain high level of phenolic components, especially gallic acid (102.57 μg/g dry matter), and suggested that safflower could be used a strong antioxidant in food and pharmaceutical products (Salem, Msaada, Hamdaoui, Limam, & Marouk, 2011, Salem et al., 2014). However, the utilization of safflower red pigments as a colorant and antioxidant in meat products has not been studied. Based on the adsorbability between carthamin and cellulose, it could be anticipated wheat fiber colored with safflower red pigments can partially replace the functions of nitrite on color formation and lipid oxidation of meat products.

Therefore, the objectives of this study were to develop a multifunctional dietary fiber as a natural colorant and antioxidant and to evaluate the effects of nitrite and wheat fiber colored with safflower red pigments on the color characteristic and lipid oxidation of cooked sausages.

2. Materials and methods

2.1. Raw material and additives

Fresh pork hams (*Musculus biceps femoris*, *M. semitendinosus*, and *M. semimembranosus*) and pork back fat were purchased from a local processor at post-mortem 48 h. Shade-dried safflower (*C. tinctorius* L.) petal was purchased from a local food market after the harvest within three months. The wheat fiber (Vitacel® Wheat Fiber-200, Barcelona, Spain), which contains approximately 74% cellulose and 26% hemicellulose (Sánchez-Alonso, Haji-Maleki, & Borderias, 2007), was also purchased.

2.2. Extraction of safflower red pigment and coloring of wheat fiber

The extraction of safflower red pigment and coloring of wheat fiber were conducted with the modification method described by Yoon et al. (2001). The safflower petal was finely ground with a food blender in order to easily extract the safflower pigments. The ground safflower petal was placed in a cheese cloth bag and washed with water, at the top, for twenty-four hours to remove safflower yellow pigment, which is water-soluble. To extract safflower red pigments, which are solubilized in alkali condition, the washed safflower petal was added to ten volumes (v/w) of 0.1 N potassium carbonate solution (K_2CO_3) and stirred for twenty-four hours. To eliminate the petal, the extract solution passes through 2–3 layers of cheese cloth, and pH of the extracts solution (yellow color) was adjusted with 0.1 M acetic acid solution until pH 5.5–5.7 to red color of expression. And then, the colored wheat fiber was prepared as follows; the wheat fiber (WF) was colored with the safflower red pigment solution (1:10 ratio) and stirred for 12 h. After coloring, the wheat fiber colored with safflower red pigments (WFC) in the solution was separated with centrifugation at 6000 *g* for 15 min at 4 °C, and the supernatant was discarded and the residues was collected. The residues obtained were dried in a 50 °C hot-air dryer (Enex-Co-600, Enexs, Korea) for twenty-four hours. The dried residues were powdered using a food blender, and the powder was passed through the 270 mesh testing sieves. The WFC collected was used to manufacture cooked sausages (Fig. 1).

2.3. Manufacturing of cooked sausages

Six cooked sausages varying in sodium nitrite (0 and 120 ppm) and WFC (0, 1, and 2%) according to a 2 × 3 factorial design were prepared. All treatments were formulated with pork meat 900 g, pork back fat 300 g, ice 300 g, sodium chloride (NaCl) 22.5 g, and sodium tri-polyphosphate (STPP) 4.5 g. The cooked sausages were prepared with the procedures of Kim et al. (2014).

2.4. Scanning electron microscopy

The ultrastructure of WF and WFC was observed using scanning electron microscopy (SEM). Samples were gold-coated using an ion sputter (E-1010, Hitachi, Tokyo, Japan), and the coated samples were scanned using electron microscopy (SEM, S-3000N, Hitachi) under standard procedures.

2.5. Proportions of myoglobin related pigments

The proportions of myoglobin related pigments, oxymyoglobin ($MbFe^{2+}O_2$), deoxymyoglobin ($MbFe^{2+}$), and metmyoglobin ($MbFe^{3+}$) in meat batter were determined with method of Krzywicki (1982) described by Carlez, Veciana-Nogues, and Cheftel (1995).

2.6. Cooking yield

The cooking yields of cooked sausages were determined by calculating the difference in weight after and before cooking (Kim et al., 2014).

2.7. Color measurement

The color of cooked samples was determined with a colorimeter (Minolta Chroma meter CR-210, Osaka, Japan; illuminate C, calibrated with a white plate, CIE $L^* = +97.83$, $a^* = -0.43$, $b^* = +1.98$), equipped with a 50-mm aperture. The setting for the illuminant was C illuminant source and the standard observer was 2°. Measurements were taken from the cross-section of the sample. The CIE L^* (lightness), a^* (redness), and b^* (yellowness) values were recorded. The hue angle and chroma were calculated as follows; hue angle $= \tan^{-1}(a^*/b^*)$ and chroma $= [(a^*)^2 + (b^*)^2]^{1/2}$ (Deda, Bloukas, & Fista, 2007).

2.8. Nitrosoheme pigments content

The nitrosoheme content were measured by the method of Hornsey (1956) described by Ahn et al. (2003). The pigments in cooked samples were extracted by aceton-distilled water solvent system. The extract was filtered with a filter paper and absorbances were measured at 540 nm. The nitrosoheme content was expressed as ppm hematin.

2.9. Residual nitrite determination

The residual nitrite in cooked sausages was determined with AOAC methods, 973. 31 (1995).