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Physical properties of wheat flour composites dry-coated with microparticulated soybean hulls and rice flour and their use for low-fat doughnut preparation

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ABSTRACT

Air-classified wheat flour was dry-coated with microparticulated rice flour (30%, db) and/or microparticulated soybean hulls (up to 10%, db) using a hybridization system, and the physical properties of the dry-coated wheat flour were examined. The composite wheat flours exhibited the higher water-holding capacity but lower swelling power and oil-holding capacity than their counterpart mixtures. In pasting viscosity, the composites of wheat and rice flours had substantially lower values for peak viscosity and breakdown than did pure wheat flour. The incorporation of soybean hulls to the composites of wheat and rice flours further reduced the peak viscosity. The composites with rice flour and soybean hulls showed slightly higher melting (gelatinization) temperatures but lower melting enthalpy compared to the counterpart mixtures. By using the composite flours for the deep-fat fried doughnut preparation, the oil uptake could be substantially reduced by approximately 30%, in comparison to pure wheat flour or the mixture samples. The composite wheat flours with microparticulated rice flour and soybean hulls produced dough matrices with improved compactness and cell structure, which were attributed to the reduced fat uptake during frying.

1. Introduction

Deep-fat frying is one of the popular cooking processes to produce a variety of food products with appealing flavor and texture. Heating the food materials in the presence of oil creates a crispy crust and a tender interior. New tastes and odors could also be generated by the thermal reactions with or without oil. Water in the foods rapidly evaporates from the crust during deep-fat frying, making the moisture migrate from the core to the crust of the fried foods. The fat may penetrate inside food matrices through the space where water has evaporated. It was reported that the total volume of oil or fat in fried foods was almost equal to the total volume of water that had been removed (Pinthus et al., 1993). In most cases, large amounts of fats remain in the fried foods, often reaching 1/3 of the total weight of the foods. The fat in the fried foods raises total calorie and possibility of oxidative deterioration. Reduction of the residual fat in the deep-fat fried foods thus has been extensively studied, and novel formulations, often with specific ingredients, have been developed to decrease the fat content.

Wheat flour (WF) is a common batter material mostly used for deep-fat frying. Starch is a major component of wheat flour, and often added to wheat flour batters to improve the texture and eating quality of the fried foods. Starch in flours becomes swollen and gelatinized during frying, forming a barrier against oil penetration and water loss (Gibney et al., 1999; Shih and Daigle, 1999). This thermal transition of starch is, therefore, important in determining the texture of the batter coating and the quality of finished products. Additionally, any ingredients that affect the thermal transition of starch may also affect the quality of the fried products. Han et al. (2007) reported that the addition of a mildly modified corn starch in wheat flour batters can reduce oil uptake and improve crispness. Gluten in wheat flour batters undergoes structural changes during frying, providing a desirable texture and eating quality (Loewe, 1993). Rice flour is often used as a substitute for wheat flour, which effectively decreases the oil uptake during frying, but may reduce the thickening property of the batter (Shih and Daigle, 1999). Cellulose derivatives such as hydroxypropyl methyl cellulose (HPMC) and methyl cellulose (MC), as well as other hydrocolloids such as gum arabic, carrageenan, and guar gum are often used as ingredients to wheat flour batters to reduce fat absorption of the fried foods (Annapure et al., 1999; Meyers, 1990). Soybean hulls, which are by-products of soybean processing contain a large amount of dietary fibers, and have been used as

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a batter ingredient to decrease the fat contents in cakes and cookies (Ku et al., 1996). Combining different flours and ingredients may exert unique effects on the overall quality of batters. Formulation of the batters using those ingredients is important in achieving the maximum effects in reducing fat uptake and improving eating quality.

Substitution of WF is usually accomplished by simply blending different flours or ingredients with WF. However, the technology for the composite formation using excessive physical forces affects the functionality and quality of batter. Coating with dry particles is one of the methods for the formation of composites (Pfeffer et al., 2001). Fine powders may be directly attached to the surface of larger core particles by mechanical means without using any solvents, binders, or water. This dry-coating process is widely used in diverse industrial materials such as UV protection cosmetics, metal/ceramic composites, thermal spray materials, ceramic filters, and electric contact materials (Naito et al., 1993). In our precedent study, WF composites with soybean hulls were prepared by a dry-coating process for applications as batters and doughnut dough. It was reported that the composite formation was effective in reducing the oil uptake (Kim et al., 2008; Lee et al., 2008). However, no study with the composites of different flours including rice flour as a frying batter has been carried out. In the present study, the physical properties and oil uptake of the frying batters of wheat flour composites dry-coated with microparticulated rice flour (RF) and soybean hulls (SH) were investigated.

2. Materials and methods

2.1. Materials

Soybean hulls were provided by Shindongbang Co. Ltd. (Seoul, South Korea). Wheat flour (9% protein, CJ Cheiljedang Co. Ltd., Seoul, South Korea) and rice flour (Japonica, Surachung, South Korea) were purchased from a local grocery store in Seoul, Korea. Soybean oil (CJ Cheiljedang Co. Ltd.) was used as frying oil. Soybean hulls and rice flour were ground by a pin mill (Gyung-Chang, Ltd., Daegu, South Korea), then microparticulated by using a jet mill (model 100AFG, Alpine Aktiengesellshaft, Augsburg, Germany) at a cutoff wheel speed (CWS) of 10,000 rpm.

2.2. Air-classifying wheat flour and rice flour

Wheat flour was separated into coarse and fine fractions (60.69 μm and 17.44 μm, respectively) by air-classification at a wheel speed (ACWS) of 3000 rpm using an air-classifying system (model 50 ATP, Alpine, Augsburg, Germany) as previously described (Bauder et al., 2004), and the coarse fraction was used for dry coating (Lee et al., 2008). The microparticulated rice flour (RF) was also air-classified at a wheel speed of 10,000 rpm to obtain a fine fraction (6.16 μm).

2.3. Preparation of composites

The air-classified wheat flour was dry-coated with the microparticulated soybean hulls (SH, 6.06 μm), with or without rice flour (referred to as WS-C and WRS-C, respectively) using a hybridization system (NHS-0, Nara Machinery, Tokyo, Japan) as previously described (Pfeffer et al., 2001). Different contents of soybean hulls (up to 10% of wheat flour) but a fixed content of rice flour (30% based on wheat flour) were used. For comparison, blends of wheat flour with microparticulated soybean hulls and/or rice flour (referred to as WS-M, and WRS-M, respectively) were prepared and tested at the same ratios in the composites.

2.4. Physical properties of mixtures and composites

2.4.1. Water-holding capacity (WHC) and oil-holding capacity (OHC)

Both WHC and OHC were determined following the methods of Chau and Huang (2003), with modifications. Flour samples (1 g, dry basis) were dispersed in distilled water or vegetable oil (1:10, weight ratio) and then the dispersions were magnetically stirred for 30 min at room temperature. After a centrifugation (800× *g*, for 30 min, 5810R centrifuge, Eppendorf, Harburg, Germany) of the dispersions, the volume of supernatant was measured to calculate the WHC or OHC.

2.4.2. Swelling property

Swelling property was measured using the methods of Schoch (1964) with slight modifications. Flour samples (0.5 g dry basis) were dispersed in distilled water (15 mL) in screw-cap tubes and then the dispersions were shaken in a water bath (DF-93SW, In Woo Corp., Seoul, South Korea) at 90 °C for 30 min. The dispersions were immediately cooled and centrifuged at 1200× *g* for 20 min. The amount of solids in the supernatants was measured after drying the supernatant in a convection oven at 120 °C for 6 h to measure the solubility. The wet precipitates were weighed and then the swelling percentage was calculated following the equations below.

$$\begin{aligned}\text{Swelling property (g/g)} = {} & \text{weight of precipitates (g)} \\ & \times 100/[\text{weight of the flour (g)} \\ & \times (100 - \text{solubility})]\end{aligned}$$

$$\begin{aligned}\text{Solubility(\%)} = {} & \text{weight of dry solids in supernatant(g)} \\ & \times 100/\text{weight of the flour(g)}\end{aligned}$$

2.4.3. Pasting viscosity

Pasting viscosity of pure wheat flour, physical mixtures and composites with soybean hulls and/or rice flour was measured using a Rapid Visco-Analyzer (RVA, Newport Scientific, Warriewood, Australia). The mixture and composite flours dispersed in distilled water (7% w/w, db) were incubated at 50 °C for 1 min, heated to 95 °C at a rate of 12.2 °C/min, held at 95 °C for 2.5 min, cooled to 50 °C at 12.2 °C/min, and then held at 50 °C for 2 min. Peak viscosity, breakdown, setback, final viscosity, and pasting temperature were determined from the viscograms.

2.4.4. Thermal transition property

Thermal transition properties of wheat flour, physical mixture and composite samples were measured using a differential scanning calorimeter (DSC6100, Seiko Instruments, Chiba, Japan). Each sample (3 mg, dry basis) was placed in an aluminum pan (Seiko Instruments, Chiba, Japan) and distilled water (6 μL) was added. The pan was then sealed, allowed to equilibrate to ambient temperature for 1 h, and heated from 20 to 120 °C at a rate of 5 °C/min. An empty pan was used as a reference. The onset (T_o), peak (T_p), and conclusion (T_c) temperatures along with gelatinization enthalpy (ΔH) were determined from the thermograms.

2.5. Physical properties of doughnuts

2.5.1. Deep-fat frying

For the preparation of doughnuts, 100 g of sample flours, 40 g of whole egg, 15 g of butter, 3 g of baking powder, 25 g of sugar, and 1 g of salt were mixed. The dough was blended with a mixer (Bethel Ltd., Gyeonggi, South Korea) following the methods of Shih et al. (2001), then it was sheeted into discs, 3 cm in diameter and