LWT - Food Science and Technology 59 (2014) 526–532

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Effects of particle size distributions of rice flour on the quality of gluten-free rice cupcakes

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ARTICLE INFO

Article history:
Received 27 March 2012
Received in revised form
15 April 2014
Accepted 24 April 2014
Available online 14 May 2014

Keywords:
Rice flour
Particle size distribution
Gluten-free
Cupcake
Quality

ABSTRACT

The particle size distributions (PSD) of rice flour and milling processes are important in making gluten-free products. The dry rice flour was prepared by grinding dried rice grains after soaking. Effects of PSD on the quality of rice cupcakes were investigated using the newly-developed rice flour. The flour properties passed through 80, 120, 160, and 200 (<180, <125, <95, and <75 μm) meshsieves, and batters and cupcakes prepared from their flours were analyzed. The PSD patterns showed two peaks containing cells and free starch fractions, in which the starch fraction peak intensity increased as a particle size decreased. While damaged starch, water binding capacity, solubility and lightness increased, crude protein and yellowness decreased as a particle size decreased. The final and setback viscosities increased as a particle size decreased. The specific volume of cupcakes was the highest in the cupcakes made with rice flour passed through under 95 μm. Hardness and springiness decreased as a particle size decreased. The air cell sizes decreased as a particle size decreased with homogeneity. Air cell homogeneity, volume, hardness, and softness of cakes determined by the different test, and appearance, texture, and overall quality determined by the preference test were all significantly different ($p < 0.05$).

1. Introduction

Rice (*Oryza sativa* L) is one of the leading crops in the world, and an important staple diet for about 50% of the world population, mostly for people in Asian countries. In particular, Korea has become self-sufficient in rice through an increase in its annual production of rice and a decrease in its consumption (Statistics Korea, 2012). To utilize the stored domestic and imported rice, Korea has been promoting processing industries nation-wide. Moreover, Koreans' eating habits have been changed from eating traditional Korean foods to eating non-traditional Korea foods, such as bread, cakes, and pasta, which are normally made with wheat flours. If a certain portion of imported wheat could be substituted with domestic rice, the utilization of rice would likely increase and Koreans could save money to purchase wheat from foreign countries.

A new method for making rice flour involving a dry milling technique of dried rice grain after soaking for at least 6 h was developed to substitute wheat flour (Shin, Gang, & Song, 2010; Song & Shin, 2007). Unlike a wet milling technique, wet rice grains after soaking for 6 h are dried under gelatinization temperature of rice starch and then the dried grains are milled, using a pin mill with a built-in standard sieve. Although many scientists have reported that wet milling is better than dry milling in producing rice flour (Chiang & Yeh, 2002; Kumar, Malleshi, & Bhattacharya, 2008; Sharma, Chakkaravarthi, Singh, & Subramanian, 2008), the new developed rice flour also has some good processing qualities that allows for the production of rice flour as a substitute for wheat flour (Shin et al., 2010). The new method has three important characteristics – increased water absorption of rice flour during dough making, similar particle size distributions as wheat flour, and a simple processing line. An increase in water absorption causes the protein matrix holding starch granules to separate and free released starch granules (Kumar, Malleshi, & Bhattacharya, 2008; Sharma, Chakkaravarthi, Singh, & Subramanian, 2008). The particle size distribution of rice flour shows two different sized peaks similar to that of wheat flour. Higher protein content of wheat flour means less free starch granule fractions in particle size distributions. Therefore, rice milling is not only low cost but also uses all kinds of rice types, including white, brown, germinated brown, broken, and aged rice.

Celiac disease (CD) is an inherited autoimmune disorder that affects the digestive process of the small intestine. Celiac disease affects 1 in 100–200 individuals, predominantly in wheat staple

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http://dx.doi.org/10.1016/j.lwt.2014.04.042
0023-6438/

countries (Hartmann, Koehlor, & Wieser, 2006; Woodward, 2007). Untreated celiac disease can lead to the development of other autoimmune disorders, as well as osteoporosis, infertility, and neurological conditions, and, in rare cases, cancer (Briani et al., 2008; Green et al., 2003; Kent et al., 2006; Lionetti et al., 2010; Stazi & Trinti, 2007). The only effective treatment for CD is strict adherence to a gluten-free diet throughout one's lifetime, which results in clinical and mucosal recovery, when followed closely. Therefore, these patients depend on rice as an important source of carbohydrate (Bean, Elliston-hoops, & Nishita, 1983; Ji, Zhu, Qian, & Zhou, 2007; Turabi, Summu, & Sahin, 2008).

Rice is a good source for making gluten-free foods, because rice has hypoallergenic properties due to the absence of gliadin (Gujral & Rosell, 2004; Gujral, Guardiloa, Carbonell, & Rosell, 2003). Rice flour has many unique attributes, such as bland taste, white color, and ease of digestion. In addition, not only it has low levels of sodium and fat but also has low protein levels. However, despite the numerous advantages of rice flour, the lack of gluten protein makes it very difficult to form batter or dough. The main approach for the development of leavened products from gluten-free rice flours is the usage of beaten egg whites. Generally, the structure of cake is composed of gelatinized starch granules entrapped with foam forming egg white protein, because the role of gluten is not important in cake batter. Both flour and eggs contain the proteins that provide strength and structure to cakes. Rice flour instead of wheat flour provides structure of cakes when its starch gelatinizes and linear amylose makes gel, and the structural strengthening effect of cake flour and egg is balanced by the tenderizing effect of the sugar and fat ingredients.

The particle sizes of rice flour were distributed in two peaks consisting of a small starch granule fraction and a rice flour particle, including a cell fraction. The peak of the small sized fraction increased with increasing sieve mesh number built in the mill (Song & Shin, 2007). Determining the particle size range of rice flour is an important factor to consider for rice processing.

The objectives of this study were to compare the properties of rice flour passed through different sieve sizes, observe the rheological properties of rice batters, and investigate color, specific volume, texture properties, and sensory evaluations of quality characteristics of cupcakes prepared from rice flour.

2. Materials and methods

2.1. Materials

The non-waxy white rice, Hopyungbyeo, was purchased from Gangjin Nonghup (Gangjin County, Jeonnam, Korea) in 2009. Other ingredients, eggs, sugar, salt, rice wine, and soy bean oil were purchased from a common market.

2.2. Preparation of rice flour

Rice flour was prepared by the dry milling method from dried rice grains after soaking (Shin et al., 2010). Rice grains were washed 3 times, soaked at 18 ± 3 °C for 6 h, and dried at 18 ± 3 °C with ventilation until the moisture content of rice grains was 12–14 g/100 g. Milling was performed using a pin mill (Pyungjin Machinery Co., Seoul, Korea) built in 80, 120, 160 or 200 mesh standard sieve, respectively. Rice flour of different particle sizes was stored in a 4 °C refrigerator until use.

2.3. Determination of rice flour properties

Moisture (Method 44-15A), protein (Method 46-11A), ash (Method 08-01) and lipid (Method 30-10) contents of rice flour were measured according to AACC methods (2000). The amylose content of rice flour was determined using starch isolated from rice, according to Williams, Kuzina, and Hlynka (1970). Water binding capacity (WBC), swelling power (SP) and solubility at 80 °C of rice flour were measured using Medcalf & Gilles' (1965), and Schoch methods (1964), respectively. Color values were assessed using a Chroma meter (Minolta CR-300 series, Tokyo, Japan) and Hunter L (lightness), $+a$ (redness), and $+b$ (yellowness) values were measured. The L, a, and b values of a standard white plate were 96.54, 0.07 and 1.90, respectively.

2.4. Analysis of particle size distributions

The particle size distributions of rice flour passed through different sized standard sieves were measured using the LS Particle Size Analyzer (Model LS 100Q, Brea, CA, USA). The particle size was analyzed using rice flour dispersed in ethanol.

2.5. Rapid Visco-Analyzer

The pasting behaviors of rice flour were investigated with a Rapid Visco-Analyzer (RVA, Model 3D, Newport Scientific Pty., Ltd., Narranbeen, Australia), according to AACC Method (2000). Rice flour (3 g, on 12 g/100 g moisture basis) was thoroughly mixed with distilled water (25 mL). The temperature was maintained at 50 °C for 1 min and then raised to 95 °C for 4.45 min. The sample was maintained at 95 °C for 2.5 min, cooled to 50 °C for 4 min, and maintained at 50 °C for 1.5 min. The initial pasting temperature, peak viscosity (P), trough viscosity (T), final viscosity (F), breakdown viscosity ($P-T$), and setback viscosity ($F-T$) were determined.

2.6. Rice cupcake making

The cup cake formula for 18 cupcakes consisted of 150 g rice flour with different particle size distributions, 120 g sugar, 2 g salt, 300 g egg, 30 g rice wine and 30 g oil. The egg, sugar and salt were mixed well in a water bath (50 °C) and the mixture was transferred to a 2.84 L Hobart mixing bowl. The mixture was mixed at a high speed to form foam and to be made to homogenize generously at a low speed. Rice flour, which has been sifted twice, was added and all the ingredients were mixed with a flat beater at a low speed for 30 s. The cake batter was scraped down, and the rice wine and oil were added into bowl and mixed well. The gravity of rice flour batter was adjusted to 0.38 similar to regular cupcake batter using wheat flour and the batter was transferred to 18 baking cups (∅ 10 cm, 35 g). Baking was performed in an oven at 180 °C top and 150 °C bottom (Deck oven, Sam Mi Ind. Co., Seoul, Korea) for 15–20 min. Then it was left to cool in the cup for 1 h.

2.7. Evaluation of cake quality

Cake volume was measured by the seed displacement method (AACC 72-10), and specific volume was calculated from the volume divided by weight. The shapes of the whole cake and cross sections were observed using a digital camera (Canon EOS 400D, Tokyo, Japan). The textural properties of the cake crumbs were measured using a compression test with a Texture Analyzer (TA, Model TA-XT plus, Surrey, England). The measuring conditions were a sample size of 1 × 1 × 1 cm, load cell of 1.0 kg, probe diameter of 2.0 cm, and deformation rate of 75%. Hardness, cohesiveness, springiness, and chewiness were measured from the texture profile analysis. The rice cupcakes were evaluated by a difference test with a nine-point test (1 = very weak, 9 = very strong) using 12 trained panelists (Png, Johnson, Barbeau, & Stewart, 1991). The trained panel groups were graduate students major in Food and Nutrition. The samples