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Particle size distribution of soy flour affecting the quality of enriched gluten-free cakes

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In this study, soy flour of three particle sizes (<132, 132–156 and >156 μm) were used to substitute 15% and 30% of starch in layer and sponge cakes formulations. Batter microstructure, density and viscosity, and cake specific volume, texture and colour were evaluated. Results showed that soy flour incorporation in layer cakes decreased batter density as its particle size increased and also increased batter viscosity. However, batter prepared with intermediate flour particle size led to the lowest viscosity while the coarse fraction presented the highest viscosity. In sponge cakes, soy flour incorporation increased batter density. At 30%, the fraction with the larger particle size had the lower density. Batter viscosity was only affected in the case of 30% soy flour substitution, being significantly decreased with the use of the fine fraction. Enrichment of layer cakes did not affect their specific volumes but a flattened shape was obtained. Soy flour incorporation decreased layer cakes hardness. In contrast, its incorporation reduced the sponge cake specific volume as the addition percentage and the particle size increased. Soy flour incorporation prevented cakes from staling during storage.

1. Introduction

In recent years, there has been an increasing interest towards gluten-free bakery products. Pathologies related to gluten intake such as celiac disease has an estimated prevalence of 1–2% worldwide (Rodrigo, 2006) while wheat allergy and gluten sensitivity affect 0.2–0.5 and 6% of USA population, respectively (Rosell, Barro, Sousa, & Mena, 2014). Therefore, the consumption of gluten-free products is higher and more frequent. Nevertheless, the quality of gluten-free products is still deficient and their nutritional value is poorer compared to those containing gluten (Matos & Rosell, 2011).

Most gluten-free products available on the market are made from starches, which leads to products with low fiber and protein content in comparison with similar products containing gluten. Leguminous flours have always been very popular featuring as supplementary ingredients in bakery products due to their high protein content and because their amino acids are well complemented with those present in cereals (Chavan & Kadam, 1993). Soybean meal also has nutritional benefits as it possesses anticancer power, reduces the risk of cardiovascular diseases and prevents from aging diseases (Friedman & Brandon, 2001; McCue & Shetty, 2004). However, although some researchers have studied the incorporation of soy protein in cakes or muffins made with starch, wheat flour (Majzoobi, Ghiasi, Habibi, Hedayati, & Farahnaky, 2014; Ronda, Oliete, Gomez, Caballero, & Pando, 2011; Sung, Park, & Chang, 2006) or rice flour (Matos, Sanz, & Rosell, 2014), or even the addition of soy flour to microwaved cakes (Sakiyan, 2015), studies about the incorporation of soy flour in cakes as well as the influence of the flour particle size on cakes have not been carried out.

It is well known that the type of flour has a significant effect on cake quality (Gomez, Oliete, Rosell, Pando, & Fernandez, 2008; Oliete et al., 2010), and that flour particle size is one of the most influential factors both in wheat (Gaines, 1985; Gomez, Ruiz-Paris, & Oliete, 2010) and gluten-free cakes (de la Hera, Martínez, Oliete, & Gomez, 2013).

The present work aims to study corn starch cake enrichment with soy flour and to evaluate the effect of its particle size on the

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cake quality. Therefore, layer and sponge cakes were made by partially replacing corn starch by soy flour of three different particle sizes at percentages of substitution of 15 and 30%. Both flour composition and microstructure were assessed and batter microstructure, density and viscosity were characterized. The volume and texture of the final products were also evaluated.

2. Materials and methods

2.1. Materials

Soy flour enzymatically inactive used in this work was from Harinera Polo (Zaragoza, Spain). The composition, provided by the supplier, was: 10 g/100 g humidity, 4 g/100 g ash, 38 g/100 g protein, 22 g/100 g fat and 2 g/100 g lecithin. Different particle sizes were obtained by sieving the flour in a Bühler MLI 300B sifter (Uzwil, Switzerland). Thus, three fractions were separated; >156 μm (coarsest), 132–156 μm (intermediate, representing circa 40% of the original flour) and <132 μm (finest). Native corn starch was provided by Daesang Corp (Seoul, Korea). The baking powder "25x1" and the emulsifier "SuperMixo T500" were both from Puratos (Gerona, Spain). Sugar, sunflower oil, milk, powdered milk and liquid pasteurized whole eggs were purchased from local market.

2.2. Methods

2.2.1. Proximate composition and particle size distribution of soy flours

Moisture (method 925.10), ash (method 923.03), fat (method 920.85), protein (method 945.18B) and fiber (method 920.86) contents were determined in triplicate according to AOAC procedures (AOAC, 1990). The nitrogen content was calculated and multiplied by 6.25 to obtain the crude protein content. The carbohydrate content was calculated by difference.

The volume fraction-length mean diameter ($d_{4,3}$) of the three particle sized flours were determined using a laser diffraction technique with a Malvern Mastersizer 3000 E (Malvern Instruments Ltd., Malvern, Worcestershire, UK).

2.2.2. Microstructure of soy flour determined by environmental scanning electron microscopy (ESEM)

ESEM of the three fractions of soy flour was carried out using a microscope Quanta 200 F, (Hillsboro, Oregon, USA). The sample was placed on a specimen holder with the help of double-sided scotch tape. Experiments were carried out under high vacuum space and a Back Scattered Electron detector. The magnification and accelerating voltage are showed on each SEM image.

2.2.3. Cakes preparation

Two types of cake were made, layer and sponge cakes. Formulations and recipes of different cakes are given in Table 1. Layer cakes were made with a single-bowl mixing procedure. All ingredients were mixed for 1 min at speed 4 (135 rpm), and 9 min at speed 6 (180 rpm) using a Kitchen-Aid Professional mixer; KPM5 (KitchenAid, St. Joseph, Michigan, USA). Then, 185 g of cake batter were placed into baking aluminum pans (109 × 159 × 38 mm) and baked. Sponge cakes were made with a creaming–mixing procedure. Sugar, liquid pasteurized egg, water and emulsifier were mixed using a Kitchen-Aid Professional mixer (Kitchen Aid, St. Joseph, MI, USA) for 2 min at speed 6 (180 rpm). After that, the powdered milk, soy flour and corn starch were added and the mixing process was continued for 3 min at speed 8 (225 rpm). Cake batter (100 g) was placed into oil-coated aluminum pans (109 × 159 × 38 mm), and baked. For both cakes, baking was performed at 190 °C for 25 min in a preheated electric oven (Salva, Lezo, Spain). After baking, cakes were left to cool for 60 min at room temperature. Then, they were removed from the pans and were packaged in polyethylene bags and finally stored at 20 °C until further analyses. For each type of cake, a control cake was prepared (100% corn starch) and each of the three different particle sizes of the soy flour was used to replace the corn starch at levels of 15% and 30%. Two replicates of each preparation were made.

Table 1
Formulation of layer and sponge cakes made replacing corn starch by soy flour at different percentages (0, 15 and 30%).

	Layer cake			Sponge cake		
	0	15	30	0	15	30
Corn starch	350	297.5	245	245	208.25	171.5
Soy flour[a]	–	52.5	105	–	36.75	73.5
Sugar	315	315	315	240.5	240.5	240.5
Milk	210	210	210	–	–	–
Powdered milk	–	–	–	25	25	25
Liquid egg	175	175	175	344	344	344
Sunflower oil	105	116.7	116.7	–	–	–
emulsifier	–	–	–	14	14	14
Water	–	–	–	55	55	55
Baking powder	10.5	10.5	10.5	–	–	–

[a] Soy flour of three different particle sizes was used.

2.2.4. Batter characterization

Batter measurements were performed twice immediately after their preparation. Batter density was measured using a pycnometer Elcometer 1800 (Elcometer, Manchester, UK). Viscosity of batter was determined using a Rapid Viscoanalyser (RVA-4) (Newport Scientific model 4-SA, Warriewood, Australia). Sample batter (15 g for sponge cake batter and 25 g for layer batter) was placed in the RVA aluminum canister with a plastic paddle. The viscosity of the batter was recorded at 30 °C after stirring for 3 min at 160 rpm.

Batter bubbles were examined using a DM750 microscope (Leica Microsystems, Wetzlar, Germany) with 40 and 100× magnification, and fitted with an EC3 video camera and images were captured using LAS EZ software (Leica Microsystems, Wetzlar, Germany). In order to visualize bubbles, a drop of batter was placed on a microscope slide and covered with a coverslip. The slides were then compressed under a 1 kg weight to create a layer of uniform thickness.

2.2.5. Cake quality evaluation

Cake quality was assessed on two cakes from each type 24 h after baking. Cake volume was determined using a laser sensor with the Volscan Profiler volume analyser (Stable Mycrosystems, Surrey, UK). The specific volume was calculated as the ratio between the volume of the cake and its weight. Weight loss was calculated as the ratio between weight of batter in the pan before baking and the weight of the cake after baking, expressed as a percentage.

The textural properties of the cake were measured with a TA. XT2 Texture Analyzer (Stable Micro Systems, Godalming, U.K.) and the Texture Expert Exceed software for data analysis. Texture Profile Analysis (TPA) test was carried out using a cylindrical aluminium probe (25 mm diameter) and a double compression test to compress crumb samples to 50% of their original height at a speed of 2 mm/s. Measurements were carried out on two slices (20 mm thickness) taken from the centre of each cake. The textural parameters considered were hardness (peak force of the first compression cycle, in N), cohesiveness (ratio of positive force area during the second compression to that during the first compression area, dimensionless), and springiness (ratio of the time duration of force input during the second compression to that during the first