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Particle size distribution of rice flour affecting the starch enzymatic hydrolysis and hydration properties

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ABSTRACT

Rice flour is becoming very attractive as raw material, but there is lack of information about the influence of particle size on its functional properties and starch digestibility. This study evaluates the degree of dependence of the rice flour functional properties, mainly derived from starch behavior, with the particle size distribution. Hydration properties of flours and gels and starch enzymatic hydrolysis of individual fractions were assessed. Particle size heterogeneity on rice flour significantly affected functional properties and starch features, at room temperature and also after gelatinization; and the extent of that effect was grain type dependent. Particle size heterogeneity on rice flour induces different pattern in starch enzymatic hydrolysis, with the long grain having slower hydrolysis as indicated the rate constant (k). No correlation between starch digestibility and hydration properties or the protein content was observed. It seems that in intact granules interactions with other grain components must be taken into account. Overall, particle size fractionation of rice flour might be advisable for selecting specific physico-chemical properties.

1. Introduction

Rice varieties are mostly designated to be consumed as intact kernels, but lately a significant raise in the rice flour production is observed (FAOSTAT, 2012) due to its employment in novel foods such as baby and gluten-free based goods. Rice is mainly composed of starch (Champagne, Wood, Juliano, & Bechtel, 2006), which determines the eating quality of cooked rice (Moldenhauer, Gibbons, & McKenzie, 2006).

Rice grinding has been used as physical treatment to reduce particle size and obtain rice flour. However, although grinding is necessary to reduce particle size, it also entails damage to starch granules by the disruption of the granular structure (Level 5) of starch (Tran et al., 2011). The size of starch granules varies between non-waxy and waxy, long and short-grain rice starches and it also varies from cultivar to cultivar (Hoover, Sailaja, & Sosulski, 1996; Wani et al., 2012). Numerous studies have analyzed the effect of mill type on the rice flour particle size distribution. Nishita and Bean (1982) were pioneers clarifying the impact of grinding methods on rice flour properties and later on, higher water binding capacity and swelling power were observed when intensifying milling (Perdon, Siebenmorgen, Mauromoustakos, Griffin, & Johnson, 2001). It seems that the range of particle size distribution is dependent on the mill used for grinding, and pin-milled and hammer-milled flours show the lowest granulation (Nishita & Bean, 1982). Moreover, the heat exposure of rice during grinding could change flour characteristics, for example the content of starch damage. Hammer and roller – milled flours had the highest value of starch damage, besides the highest flour temperature after grinding. Kadan, Bryant, and Miller (2008) investigated the characteristics of commercial long-rice flour ground in two steps with a hammer-mill and a turbo mill, stating that current methods used to make commercial rice flour do not produce uniform particle size. Particle size heterogeneity significantly affects the physicochemical properties of the flours by increasing the surface area per volume unit and also it can increase the bioavailability of macronutrients (carbohydrate, proteins) by raising the rate of digestion which readily would affect human nutrition (Wondra, Hancock, Behnke, & Stark, 1995). That fact has been confirmed in barley and sorghum flour in which the kinetic of starch digestion by alfa-amylase was dependent on the particle size of the flours (Al-Rabadi, Gilbert, & Gidley, 2009). Considering that nutrient distribution in grain fragments varies with particle size it is understandable and expected that their functionality and processing performance vary with the particle size. In fact, particle size fractionation by air classification or sieving has been proposed as strategy for adding value to coarsely milled grain like obtaining beta-glucan enriched fractions from barley milling stream (Sundberg, Tilly, & Aman, 1995). Despite the potential of that strategy only sorghum and

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barley have been targeted as cereals for improving digestibility and nutritional potential. Recently, de la Hera, Talegón, Caballero, and Gómez (2012) stated the influence of particle size of corn flour on gluten free bread performance concluding that coarser flours (>180 μm) provide breads with higher volume and softer crumbs due to their ability to retain carbon dioxide during proofing, whereas finer flours (<106 μm) are more suitable for cakes (Hera, Martínez, Oliete, & Gómez, 2012).

In spite of the increasing consumption of rice flours, there are no studies focussed on the effect of particle size distribution on the physico-chemical properties and starch digestibility. Previous works characterized rice flour and checked the influence of particle size but focussing on flour obtained from different grinding methods. The aim of this research was to evaluate the degree of dependence of the rice flour functional properties, mainly derived from starch behavior, with the particle size distribution of rice flour obtained by sieving, namely flour properties and starch features regarding enzymatic susceptibility. With that purpose two different rice cultivars were selected to determine the incidence of kernel hardness in those properties.

2. Materials and methods

2.1. Materials

Two rice grain types, one short and one long, were purchased from the local market and ground in a hammer mill, 200 μm of screen (LM 3100) (Perten Instruments, Hägersten, Sweden). Flours were sifted in a Bühler MLI 300B (Bühler AG, Uzwil, Switzerland) with screens of 80, 132, 150 and 180 μm during 15 min to obtain 5 fractions.

2.2. Methods

2.2.1. Particle size and protein determination

Flours were analyzed following AACC method (AACC, 2012) for protein (AACC, 46-30.01). Determinations were carried out in duplicate. The particle size distribution was measured using a particle size analyzer with laser diffraction Helos & Rodos (Sympatec, Clausthal-Zellerfeld, Germany). Short grain rice, fraction <80 μm (average 44 μm), 80–132 fraction (average 122 μm), 132–150 fraction (average 143 μm), fraction 150–180 (average 176 μm), >180 (average 340 μm). Long grain rice, fraction <80 μm (average 48.55 μm), 80–132 fraction (average 125 μm), 132–150 fraction (average 147 μm), 150–180 fraction (average 171 μm), and >180 (average 316 μm).

2.2.2. Determination of damaged starch content

The starch damage content in the flour samples was determined in accordance with the AACC method (AACC, 2012), by using Megazyme starch damage kit (Megazyme International Ireland Ltd., Co., Wicklow, Ireland). Absorbance was read at 510 nm in a microplate reader BIOTEK EPOCH (Izasa, Barcelona, Spain). The starch damage was determined as percentage of flour weight on dry basis. Three replicates were made for each sample.

2.2.3. Flour hydration properties

The water holding capacity (WHC) defined as the amount of water retained by the sample without being subjected to any stress was determined mixing flour (1.000 ± 0.005 g) with distilled water (10 ml) and kept at room temperature for 24 h. The supernatant was decanted. WHC was expressed as grams of water retained per gram of solid.

The swelling volume was determined following the method reported by Gularte and Rosell (2011) with slight modification. Samples (1.000 ± 0.005 g) were placed in a graduated cylinder and mixed with distilled water (10 ml), then kept at room temperature for 24 h. The swelling volume was calculated by dividing the total volume of the swollen sample and the original dry weight of the sample.

The water binding capacity (WBC) defined as the amount of water retained by the sample under low-speed centrifugation was determined as described the standard method (AACC, 2010). Samples (1.000 ± 0.005 g) were mixed with distilled water (10 ml) and centrifuged at 2000 × *g* for 10 min. WBC was expressed as grams of water retained per gram of solid. Flour hydration properties were analyzed in triplicate.

For the determination of oil absorption capacity (OAC), the method of Lin, Humbert, and Sosulski (1974) was followed. Briefly, rice flour (100.0 ± 0.2 mg) was mixed with 1.0 ml of vegetable oil. The content was stirred for 1 min with a wire rod to disperse the sample in the oil. After a period of 30 min in the vortex mixer, tubes were centrifuged at 3000 × *g* and 4 °C for 10 min. The supernatant was carefully removed with a pipette and tubes were inverted for 25 min to drain the oil and the residue weighed (W_r). The oil absorption capacity was expressed as grams of oil bound per gram of the sample on dry basis. Three replicates were made for each sample. OAC was calculated by Eq. (1):

$$\mathrm{OAC\,(g/g)} = \frac{W_r}{W_i} \quad (1)$$

where W_i was the sample weight (g, db).

2.2.4. Gel hydration properties

Water absorption index (WAI) or swelling capacity and water solubility index (WSI) of different rice flour fractions were determined following the method of Toyokawa, Rubenthaler, Powers, and Schanus (1989), with slight modification as reported Rosell, Yokoyama, and Shoemaker (2011). Briefly, flour (50.0 ± 0.1 mg) sample was dispersed in 1.0 ml of distilled water in an eppendorf tube using a wire rod and cooked at 90 °C for 10 min in a water bath. The cooked paste was cooled in an ice water bath for 10 min, and then centrifuged at 3000 × *g* at 4 °C for 10 min. The supernatant was decanted into an evaporating dish and the weight of dry solids was recovered by evaporating the supernatant at 105 °C till constant weight. Four replicates were made for each sample. Residues (W_r) and dried supernatants (Ws) were weighed and WSI or swelling capacity, solubility index and swelling power (SP) were calculated as follows:

$$\mathrm{WAI\ (g/g)} = \frac{W_r}{W_i} \quad (2)$$

$$\mathrm{WSI\,(g/100\,g)} = \frac{W_s}{W_i} \times 100 \quad (3)$$

$$\mathrm{SP\,(g/g)} = \frac{W_r}{W_i - W_s} \quad (4)$$

where W_i was the sample weight (g, db).

Values were the average from four replicates.

2.2.5. Amylose/amylopectin ratio

A change in the composition of linear or branched fractions of starch can be indicated by a change in the ratio of absorbance of iodine starch complexes at 630 and 520 nm (Sokhey & Chinnaswamy, 1992). The ratio of amylose/amylopectin was determined following the method described by Gujral and Rosell (2004). Rice flour fraction (50.0 ± 0.1 mg) was dispersed in 1.0 ml of distilled water in an eppendorf tube using a wire rod and cooked at 90 °C for 15 min in a water bath. The cooked paste was cooled in ice water bath to room temperature, and then centrifuged at 3000 × *g*