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Effects of particle size distribution on some physical, chemical and functional properties of unripe banana flour

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ABSTRACT

The objective of this study was to examine the effect of particle size distribution on physical, chemical and functional properties of unripe banana flour for the first time. A pure triploid (AAA group) of *Musa acuminata* subgroup Cavendish (°Brix;0.2, pH;4.73, titratable acidity; 0.56 g/100 g malic acid, total solids; 27.42%) which was supplied from Gazipaşa, Antalya, Turkey from October 2014 to October 2015 was used. Size fractions of <212, 212–315, 316–500 and 501–700 μm were characterized for their physical, functional and antioxidant properties. Particle size significantly effected color, water absorbtion index and wettability. L^* value decreased, a^* and b^* values decreased by increasing particle size ($r^2 = -0.94$, $r^2 = 0.72$, $r^2 = 0.73$ respectively). Particles under 212 μm had the lowest rate of wettability (83.40 s). A negative correlation between particle size and wettability ($r^2 = -0.75$) and positive correlation between particle size and water absorption index ($r^2 = 0.94$) was observed.

1. Introduction

Banana fruit (*Musa* spp.) is an important staple food crop and its production is increasing in the tropical and subtropical regions due to high export potential. Banana is easily transported and can be stored longer when unripe. On the other hand, large amounts of unripe banana rejection or post harvest loss are used as raw materials for domestic artisanal flour production (Aurore, Parfait, & Fahrasmane, 2009). Unripe banana is a promising ingredient and many researchers studied applications of unripe banana flour in various food products (Ho, Aziz, & Azahari, 2013; Karim & Sultan, 2015; Agama-Acevedo, Islas-Hernández, Pacheco-Vargas, Osorio-Díaz, & Bello-Pérez, 2012). Some researchers studied the effects of ripening stages on some physical, chemical and functional properties of foods (Onwuka & Onwuka, 2005). There are also studies on flour production from unripe banana which include comparison of physicochemical properties of banana pulp and peel flours (Alkarkhi, Bin Ramli, Yong, & Easa, 2011), production of instant unripe banana flour (Rayo et al., 2015), effect of organic acid pretreatment on some properties of unripe banana flour (Anyasi, Jideani, & Mchau, 2015) and effect of maturation steps on chemical composition of banana and plantain peels (Emaga, Andrianaivo, Wathelet, Tchango & Paquot, 2007). However, to the best of authors' knowledge, effect of particle size distribution of unripe banana flour is not studied. As a raw material for different food products, particle size of unripe banana flour is very important for quality attributes such as water holding, oil holding, water solubility, powder dispersion, wettability, bulk density and tapped density. Our former studies on product development by using UBF showed that (data not shown) batter viscosity and end product texture were highly affected by particle size as well, which made the study worthwhile to investigate the physical, chemical and functional data of UBF having different particle size distribution.

Since differences in particle size are key parameters which affect the above mentioned properties, the objective of this study was to determine the effects of particle size on some physical, chemical and functional properties of unripe banana flour. Four different size fractions (<212 μm, 212–315 μm, 316–500 μm, 501–700 μm) were chosen for comparison.

2. Materials and methods

2.1. Materials

2.1.1. Unripe banana

'Dwarf Cavendish' banana (*Musa* spp. AAA) cultivated in open-fields in the central south coast region (latitude 36°15′N, longitude 32° 17′E) of Gazipaşa, Antalya, Turkey was used in the study. Bananas (°Brix;0.2, pH;4.73, titratable acidity; 0.56 g/100 g malic acid, total solids; 27.42%) were supplied from October 2014–October 2015 in three different time intervals and characterized as unripe banana (Colour index; 2 = entirely green) according to the com-

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mercial peel color scale described by Aurore et al. (2009). They were harvested at the commercial stage, approximately 110 days after anthesis. Drip irrigation system was used. Base dressing was done using mineral fertilizer TOROS Gübre®-NPK 15-15-15 (300 g) and animal manure (40–50 kg) in the 8th month of cultivation. Fungicidal agricultural spraying is conducted once a year with Best Captan 50 WP® after fertilization and hoeing fields.

2.1.2. Unripe banana flour (UBF) production

Unripe banana fruits were hand peeled and immediately rinsed in citric acid solution(1 g/L; Rayo et al., 2015). They were cut into 2 mm slices, again rinsed in the same solution for 1 min and stored at −18 °C. The frozen slices were dried in a freeze dryer (CRYST-Alpha 2–4 LD Plus Freeze Dryer, Newtown Wem, Shropshire, UK) for 48 h, and then grounded by using a blade grinder (Retsch, GRINDOMIX GM200, Germany) to obtain UBF. UBF was passed through a sieve shaker (Şimşek Laborteknik, ES-608, Turkey) and size fractions of <212, 212–315, 316–500 and 501–700 μm were collected. They were stored at +4 °C in sealed glass containers for further use.

2.2. Methods

2.2.1. Moisture content

Moisture content of UBF was determined gravimetrically by vacuum oven drying at 70 °C until constant weight (Zenebon & Pascuet, 2005). Results were expressed as percentage.

2.2.2. Water activity

Water activity (a_w) was measured with a water activity measurement device (HygropPalm HP23-AW, ROTRONIC AG, Bassersdorf, Switzerland).

2.2.3. pH and total soluble solids (TSS)

The pH of the UBF was measured according to Suntharalingam and Ravindran (1993) with some modifications. 4% (w:v) UBF suspension was stirred for 5 min, allowed to stand for 30 min, the supernatant was transferred to a beaker and the pH of supernatant was measured by using a WTW inoLab® pH meter model pH 7110. Total soluble solids (TSS) in the same flour slurries were measured using a Refractometer (Digital Abbe Refractometer, WAY-2S, Jiangsu Zhengji Instruments *Co*., Ltd., China). Results were given as Brix.

2.2.4. Color profile of unripe banana flour

Color of UBF samples were measured by a CR-5 Konica Minolta Chroma Meter (Osaka, Japan) using CIELAB and CIELCH color scale with the parameters $L^*a^*b^*$ *and* $L^*C^*H^*$. C^* coordinate is the chroma (Eq. (1)) and H^* coordinate is the hue (Eq. (2)) (Wrolstad & Smith, 2010). The $L^*a^*b^*$ values were used for determination of Chroma C^*, Hue angle, whiteness index (WI) and yellowness index (YI) using the following equations;

$$\text{Chroma } C^* = \sqrt{(a^*)^2 + (b^*)^2} \tag{1}$$

$$\text{Hue angle } H^\circ = \tan^{-1}\left\{\frac{b^*}{a^*}\right\} \tag{2}$$

Whiteness index (WI) and yellowness index (YI) of UBF samples were calculated according to Pathare, Opara, and Al-Said (2013) by the following equations:

$$WI = 100 - \sqrt{(100 - L) * + a*^2 + b*^2} \tag{3}$$

$$YI = \frac{142,86b^*}{L^*} \tag{4}$$

2.2.5. Bulk density and tapped density

The bulk density (ρ_{bulk}) of UBF was determined by measuring the weight of the UBF and corresponding volume. Approximately 1 g of UBF was transferred to 10 mL graduated cylinder. The bulk density was calculated by dividing the mass of the UBF by the volume occupied in the cylinder. For the tapped density (ρ_{tapped}), graduated cylinder was tapped to constant volume by a glass rod. The volume of UBF was used in mass/volume calculation (Jinapong, Suphantharika, & Jamnong, 2008).

2.2.6. Carr index (flowability) and Hausner ratio (cohesiveness)

Flowability and cohesiveness of UBF were expressed in terms of Carr index (CI) (Carr, 1965) and Hausner ratio (HR) (Hausner, 1967), respectively. Both CI and HR were figured out from the bulk (ρ_{bulk}) and tapped (ρ_{tapped}) densities of the UBF as shown in the equations below:

$$CI = \frac{\rho_{tapped} - \rho_{bulk}}{\rho_{tapped}} \times 100 \tag{5}$$

$$HR = \frac{\rho_{tapped}}{\rho_{bulk}} \tag{6}$$

Powders with HR under 1.2 are classified as low cohesive group; HR between 1.2 and 1.4 are considered as intermediate cohesive and HR over 1.4 are stated as high cohesive group (Hausner, 1967). Flowability of powders with CI < 15 are classified as very good; 15 < CI < 20 as good; 20 < CI < 35 as fair; 35 < CI < 45 bad and CI > 45 as very bad (Carr, 1965).

2.2.7. Wettability

Wettability of the UBF samples were determined according to A/S Niro Atomizer (1978) with some modifications. 100 mL distilled water was poured into 250 mL beaker. A glass funnel held was set over the beaker on a ring stand with the height of 10 cm between the bottom of the funnel and the water surface. A cylinder glass rod was placed inside the funnel to block the opening of the funnel. UBF sample (0.1 ± 0.0001 g) was placed around the rod and the rod was lifted while the stop watch was started simultaneously. Finally, the time for UBF to become completely wet was recorded.

2.2.8. Water solubility index (WSI) and water absorbtion index (WAI)

WSI and WAI of UBF was performed according to Rodriguez-Ambriz, Islas-Hernández, Agama-Acevedo, Tovar, and Bello-Pérez (2008) with some modifications. 1 g UBF was transferred to 35 mL of distilled water. Mixture was homogenized with a mechanical homogenizer (JANKE & KUNKEL IKA®-Labortechnick RW20, Staufen, Germany) at level 10 for 5 min, and the solution was transferred in a 50 mL pre-weighted centrifuge tube, tube was incubated at room temperature for 1 h and centrifuged at 3000*g* for 20 min in a centrifuge device (Universal 32R/Hettich-Zentrifungen D-78532 Tuttlingen, Germany). The tube was drained into a pre-weighted petri dish at a 45° angle for 10 min and dried for 5 h at 105 °C to constant weight. The percentage of residue (mass of soluble flour, g) with respect to the amount of dry UBF sample (mass of total flour, g) used in the test was taken as WSI. WAI was calculated as the mass of centrifuged precipitate (g) per UBF sample used in the test (g).

2.2.9. Oil holding capacity (OHC)

The method of (Rodríguez-Ambriz et al., 2008) was used to determine OHC. 25 mL olive-oil were added to 1 g of UBF, vortexed with mixer (WiseMix VM-10 Vortex Mixer, New Zealand) for 2 min and incubated at room temperature for 1 h. Tube was centrifuged at 3000 g for 20 min. The supernatant was decanted and the tube