Effects of grinding methods on the characteristics of Pusa 1121 rice flour
(Kesan kaedah pengisaran pada ciri-ciri tepung beras Pusa 1121)

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Abstract
The effects of three grinding methods on the characteristics of Basmati (Pusa 1121) rice flour were investigated. Pasting behaviour of rice flour milled by the three grinding methods, namely, dry, semi-dry and wet grinding, were analysed using Rapid Visco Analyzer (RVA). The parameters analysed were pasting temperature, peak viscosity, hot paste viscosity, cool paste viscosity, breakdown viscosity and setback viscosity. These parameters were influenced by the three grinding methods. Highest breakdown viscosity was associated with wet grinding when prepared using mixer grinder. Semi-dry grinding produced flour with higher final viscosity (8270cP) compared to flours prepared by other grinding methods. The setback value was lowest in wet grinded flours followed by semi-dry and dry milled flours. The results of X-ray diffraction (XRD) pattern indicated the presence of A-type patterned starch. Higher levels of impact and compression forces acting on the rice in dry or wet grinding processes were reflected in the loss of peak intensity as a result of physical damage.

Introduction
Rice (Oryza sativa) is a principal cereal, a leading food crop of the world and a staple food of over approximately half of the world's population (Singh et al. 2003). Its annual consumption is next to wheat (Razavi and Farahmandfar 2008). It is commonly used either as brown or white rice, which is produced by removing the hull and bran layers of rough rice kernel through dehulling and milling processes respectively. Pusa 1121 is a promising Indian Basmati rice variety (Bhatia et al. 2009) known for its extra long slender grains of length up to 8.3 mm. The grain of this aromatic rice genotype highly elongates after cooking and remains non-sticky. High yielding characteristics associated with this variety has not only replaced traditional rice varieties but also gaining popularity among Indian farmers especially in the northern rice growing belt.

The extent of breakage for extra long rice kernels are much higher and thus, the degree of milling affects the head rice recovery. The levels of protein and lipid in milled white rice are mainly associated with the bran portion (Perdon et al. 2001). White rice is predominantly a starchy cereal and is comprised of endosperm portion. About 90% of dry matter of milled rice is starch and the rest are non-starch components like protein, lipids and ash (Juliano 1992).
The rice varieties are classified according to their amylose content which can either be non-waxy (varies from 8 – 37%) or waxy (glutinous) (from 0.8 – 1.3%) (Juliano and Perdon 1975). The waxy rice flour is frequently used as thickening agent for white sauces, gravies and puddings. Low amylose (9 – 20%) rice are preferred for processing crackers and biscuits, intermediate amylose (20 – 25%) rice is used for making extruded (dried) pasta and high amylose (>25%) rice are favoured for parboiled rice, rice bread and noodles.

The rice flours and starches are important ingredients in both traditional and novel foods prepared across the world (Villareal et al. 1993). Some of the traditional rice flour-based products in India are puttu, made by steaming rice flour and grated coconut, and appam, a cake formed by mixing rice flour and fermented coconut milk. Idlis and dosas are delicacies also made from rice flour batter. Absence of gluten provides an additional advantage and makes rice particularly suitable as an alternative to wheat in bakery products especially suitable for persons suffering from physiological disorder of gluten sensitive enteropathy (Prasad, Prakash et al. 2010b).

The process of grinding in making rice flour affects the physico-chemical characteristics by changing the particle size and creating differences in particle size distribution pattern (Nishita and Bean 1982). Types and degree of milling also affect the crystallinity of rice flour that control the quality of rice flour-based products (Kang et al. 2003). The main objectives of the present investigation were to assess the characteristics of rice flour using dry, semi-dry and wet grinding methods in relation to particle size distribution, x-ray diffraction patterns, degree of uniformity and pasting properties.

Materials and methods
Rice variety Pusa 1121 was procured from the local seed collection centre, Sangrur, Punjab. The paddy was cleaned from apparent foreign materials using the aspirator before dehusking in the laboratory model dehusker. The brown rice obtained was milled using the rice polisher (Indosaw Industries (P) Ltd., Ambala, India). The white rice was then placed in the rice grader (Indosaw Industries (P) Ltd., Ambala, India) to separate the head rice from brokens which were used for grinding and flour characterization purposes.

For preparation of rice flour, three methods of grinding process were adopted, i.e. dry, semi-dry and wet grinding (Figure 1). In the dry grinding process, the broken rice was directly ground into flour using the mixer grinder (Sujata, Mixer) and passed through 100 mesh sieve. In semi-dry grinding, the broken rice was soaked in distilled water at 30 ± 1 °C for 1 h (2:1), drained and spread on muslin cloth and allowed to dry for 25 – 30 min at room temperature for removal of surface moisture before grinding into semi-dry flour in the mixer grinder. The flour was then dried overnight in a hot air oven at 40 °C to reduce the moisture. The dried sample was reground into fine flour and passed through 100 mesh sieve.

For wet milling, the broken rice was soaked for 4 – 5 h and then ground in the wet grinder (Vidhya electrical (P) Ltd., Coimbatore) or mixer grinder with water twice the weight of the rice (Figure 1). The slurry obtained was dried at 40 °C for 12 h to reduce the moisture content and then reground into fine flour to pass through 100 mesh size sieves.

Chemical composition analysis
The moisture, protein, fat and ash content were determined according to AOAC (2000). The amylose content was determined based on the blue colour reaction with iodine (Juliano 1971).

Image processing
The raw image of flours was acquired using a microscope attached with a 3-mega pixel
camera. The contrast of the raw image was enhanced using histogram equalization on the raw image. Thresholding was further performed on the histogram equalized image to allow segmentation of pixels in the image into multilevel classes. Single thresholding was used, which divided the intensity value set into two non-overlapping ranges, each of which can be associated with a unique value in the resulting image (Prasad, Jale et al. 2010a). Using this technique, each pixel was classified either based on object of interest or the background of an image. The processing of the images was done using software NI vision assistance 2010 for Labview 2010 environment. Using the line profile function and particle count tool, the image was analysed to characterize the flour.

**Pasting properties**
The pasting properties of the rice flour were evaluated using the Rapid Visco Analyzer (RVA, Newport Scientific, Australia). Three g of flour was weighed directly into the aluminium RVA sample canister, and distilled water was added to a total constant weight of 28 g. A programmed heating and cooling cycle was set in samples which were held at 70 °C for 1.0 min, heated to 95 °C in 4.3 min, held at 95 °C for 2.0 min and then held for another 2.0 min at 50 °C. Parameters recorded were pasting temperature (PT), peak viscosity (PV), hot paste viscosity (HPV) (minimum viscosity at 95 °C), cool paste viscosity (CPV) (final viscosity at 50 °C), breakdown viscosity (BD) and setback viscosity (SB).

**X-ray diffraction (XRD) analysis**
The moisture content of the various rice flours varied in the range of 11.11 – 13.14% (dry weight basis). The powdered diffraction technique was applied to obtain the X-ray diffraction (XRD) pattern using an X-ray diffractometer (Rigaku Denki Co. Ltd., Japan) with the following operating conditions: 40 kV, 30 mA using Cu-Kα X-rays of wavelength (λ) = 1.54056 Å and data was taken for the 2θ range of 10 – 40° with a resolution of 0.05° step size.

**Statistical analysis**
All the experimental tests were performed in triplicate. The experimental data were statistically analysed for complete randomized block design (CRBD) using SPSS version 16.0. The measure of central tendencies and dispersions were determined and Duncan multiple range test (DMRT) was used for separation of means.
**Results and discussion**

**Physico-chemical characteristics**

The initial moisture content of dry, semi-dry and wet ground rice flour of Pusa 1121 variety were 11.11 ± 0.23, 12.11 ± 0.17 and 13.14 ± 0.24 % respectively on dry basis and the particle size varied at 51.62 ± 42.35 µm, 20.25 ± 18.98 µm and 21.08 ± 19.99 µm respectively. The particle and particle size distribution pattern are presented in Figures 2 and 3. As evident, semi and wet ground flours were uniformly distributed and had smaller particle size as compared to flour obtained under dry grinding process. The amylose content of dry ground rice flour was higher than the other two grinding methods and was significantly different at \( p \leq 0.05 \) (Table 1). The dry ground rice flour reflected higher content of protein than the semi-dry and wet ground rice flours. Fat content was not significantly different \( (p \leq 0.05) \) among the flours obtained from different grinding methods, while ash content was less in the wet ground flours.

The semi-dry and wet grinding process involved soaking of rice kernels, which resulted in leaching out of protein and other soluble substances from the surfaces of the starchy rice kernels. Medcalf and Lund (1985), Chen (1995) and Juliano and Hicks (1996) also concluded that some soluble protein, sugars and non-starch lipids were washed away during soaking of rice kernels which were subjected to semi-dry or wet grinding. Thus, higher amount of protein and ash were found in dry ground rice flour compared with the other flours (Table 1).

**Pasting characteristics**

Analysis of pasting behaviour using the Rapid Visco Analyser (RVA) is a useful method for characterizing the properties of rice flour. The pasting behaviour and visco-elastic properties of the rice flours are mainly determined by the differences in

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*Figure 2. Micrograph of Pusa 1121 rice flour particles*
Figure 3. Particle size distribution of Pusa 1121 ground rice flour

The pasting behaviour and the typical pasting curves obtained from the RVA are shown in Figures 4 and 5. The rice flour characteristics analysed by the RVA were influenced by the three grinding methods (Table 2). The pasting temperatures of semi-dry and wet ground flour (using mixer grinder) were significantly lower than the other grinding methods.

The dry ground flour showed lower peak viscosity than the semi-dry rice flour (Figure 5). The peak viscosity is a measure of the water holding capacity of the starch in terms of the resistance of swollen granules. The lower peak viscosity in dry ground flour is probably because of the higher damage caused to starch during the dry grinding process (Yoenyongbuddhagal and Noomhorm 2002). The dry and wet ground rice flour had up to 25% lower cool paste viscosity (CPV) than the CPV of semi-dry ground flour.

Dry milled flour had lower number of swollen granules and the larger particle size (Figure 3) could not expand or hydrate rapidly compared to the fine particles which expanded rapidly (Marshall 1992). The breakdown viscosity is regarded as a measure of the degree of disintegration of granules and shows paste stability. During the breakdown, the granules are disrupted
Characteristics of Pusa 1121 rice flour

Table 1. Physico-chemical characteristics of dry, semi-dry and wet grinding rice flours

<table>
<thead>
<tr>
<th></th>
<th>Dry</th>
<th>Semi-dry</th>
<th>Wet (Wet grinder)</th>
<th>Wet (Mixer grinder)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>11.11 ± 0.20c</td>
<td>12.11 ± 0.02b</td>
<td>13.14 ± 0.03a</td>
<td>13.01 ± 0.22a</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>7.24 ± 0.70a</td>
<td>0.44 ± 0.03b</td>
<td>0.39 ± 0.02b</td>
<td>0.41 ± 0.07b</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>1.32 ± 0.30a</td>
<td>1.31 ± 0.03a</td>
<td>1.30 ± 0.20a</td>
<td>1.29 ± 0.21a</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>0.65 ± 0.11a</td>
<td>0.34 ± 0.02b</td>
<td>0.31 ± 0.02b</td>
<td>0.29 ± 0.02b</td>
</tr>
<tr>
<td>Amylose (%)</td>
<td>21.32 ± 0.51a</td>
<td>17.81 ± 0.33b</td>
<td>16.21 ± 0.32c</td>
<td>15.32 ± 0.53d</td>
</tr>
</tbody>
</table>

Means in the same row followed by the same letters are not significantly different ($p > 0.05$)

Table 2. Pasting properties of dry, semi-dry and wet grinding rice flours

<table>
<thead>
<tr>
<th></th>
<th>Dry</th>
<th>Semi-dry</th>
<th>Wet (Wet grinder)</th>
<th>Wet (Mixer grinder)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasting temperature (°C)</td>
<td>59.4a</td>
<td>51.8b</td>
<td>65.5a</td>
<td>50.1b</td>
</tr>
<tr>
<td>Peak viscosity (cP)</td>
<td>4816.0b</td>
<td>5470.0a</td>
<td>4319.0d</td>
<td>4517.0c</td>
</tr>
<tr>
<td>Hot paste viscosity (cP)</td>
<td>4260.0b</td>
<td>4624.0a</td>
<td>3557.0c</td>
<td>3478.0d</td>
</tr>
<tr>
<td>Cool paste viscosity (cP)</td>
<td>7913.0b</td>
<td>8270.0a</td>
<td>5687.0d</td>
<td>6359.0c</td>
</tr>
<tr>
<td>Breakdown viscosity (cP)</td>
<td>556.0d</td>
<td>846.0b</td>
<td>762.0c</td>
<td>1039.0a</td>
</tr>
<tr>
<td>Setback viscosity (cP)</td>
<td>3653.0a</td>
<td>3646.0a</td>
<td>213.0c</td>
<td>2881.0b</td>
</tr>
</tbody>
</table>

Means in the same row followed by the same letters are not significantly different ($p > 0.05$)

![Figure 4. Typical Rapid Visco Analyser (RVA) curve for ground rice flour](image)
The viscosity increased for all three types of flours after cooling to 50 °C. The final viscosity was lower for wet and dry ground flours than the semi-dry flour (Figure 5) which had higher final viscosity (8270cP). The setback viscosity is the increase in viscosity resulting from the rearrangement of amylose molecules that have leached out from the swollen starch granules during cooling and is generally used as a measure of gelling ability or retrogradation tendency of the starch (Karim et al. 2007). The setback values were lowest for both types of wet ground flours followed by semi-dry and dry milled flours. Higher setback values for dry and semi-dry ground flours indicated the degree of recrystallization of the gelatinized starch during cooling.

**X-ray diffraction (XRD) pattern**

The effects of grinding methods on XRD pattern for Pusa 1121 flours is shown in Figure 6. The XRD pattern indicated the presence of A-type patterned starch with strong peaks at around 15.18, 17.13, 18.03 and 22.86° 20 and feeble peaks at 11.49, 20.06, 26.69 and 30.36° 20 (Vansteelandt and Delcour 1999; Noosuka et al. 2005).
Higher crystallinity could be associated with the presence of sharp peaks, which are found in the semi-dry or wet ground flours. This may be attributed to the degree of grinding and associated conversion of starch into more amorphous form. Higher levels of impact and compression forces acting on the rice in dry or wet grinding process using mixer grinder were reflected in the loss of peak intensity. The results from the physical damage of the native amylopectin lead to degradation of the starch into low molecular weight fragments which may disrupt the glycosidic linkages and the disulphide bonds of the native grain.

Conclusion
Different grinding methods resulted in variations in the physicochemical characteristics of rice flours suitable for specific uses. The grinding process reduces the rice particle size and affects the particle distribution characteristics. The semi-dry and wet grinding methods resulted in smaller particle size. The effect of grinding methods indicated the conversion of particles into more amorphous form.

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References


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