Effects of Different Grinding Methods on Chemical and Functional Properties of MR211 Rice Flour

R. Asmeda and A. Noorlaila
Faculty of Applied Sciences, Universiti Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia
Email: dnoorlaila@salam.uitm.edu.my

M. H. Norziah
Food Technology Department, School of Industrial Technology, Universiti Sains Malaysia, Minden, 11800, Penang, Malaysia

***Abstract*—Investigation on chemical and functional properties as affected by different grinding techniques was carried out during the milling process of rice grains into rice flour production. Proximate analysis revealed that dry ground flour had significantly (p<0.05) highest protein, lipid, ash and carbohydrate contents. Wet grinding technique yielded flour that exhibit significantly finest average particle size distribution (9.32μm), with significantly lowest damaged starch (4.08%) and highest L* value (93.55). Water absorption index, flour swelling volume and solubility were significantly highest in dry ground flour as compared to others. Results indicated that different grinding methods significantly affected chemical and functional properties of starch and data generated provide additional opportunities of exploiting rice flour utilization and hence boost its value-addition potentials for product development.**

***Index Terms*—chemical, functional, grinding techniques, rice flour**

I. Introduction

Rice (*Oryza sativa* L.) is one of the most important food crops as it is a staple food in the world, especially Asian countries. Rice grains are being processed using various techniques such as, grinding through mechanical forces to obtain rice flour of fine size particle. Two major components of starch in rice grains are amylose and amylopectin, which constitutes approximately 90% of milled rice on a dry weight basis [1]. The variation in the amylose/amylopectin ratio of each rice cultivar contributes to its unique functional properties, and thus makes the rice flour being used in a lot of novel foods.

Due to the mechanical processing, starch granules in the rice flour are exposed to damaged [2]; thus indicate that percentage of damage starch and distribution of the flour produced as the key factors which affect its behavior and properties; and also the application of the rice flour. Rice flour can be produced by means of different grinding methods, which urge the need to investigate the effects of the different grinding techniques on the properties of rice flour produced. Most of these studies, however, examined the rice flour characteristics from one particular grinding practice. Other than that, some of the studies on chemical and functional properties of rice flour were performed on isolated starch granules to avoid the interference from non-starch components in cereal grains [3], [4], and thus do not replicate the events occurring during grinding of cereal grains as a whole. This study aim to investigate the effect of different grinding practices in rice utilization, and filling the gap by providing specific information on chemical and functional properties of rice flour from Malaysian variety which is still lacking.

II. Material and Methods

A. Material

Malaysian rice variety of MR211 was obtained from Malaysian Agricultural Research and Development Institute (MARDI) Pulau Pinang, Malaysia. Rice paddy was harvested at maturity, cleaned, dehulled and milled to obtain milled rice grains. Only whole rice grain without any physical damage or insect infestation was selected for analysis. The chemicals were obtained from the commercial scientific suppliers. The assay kit of starch damage and amylose/amylopectin content was purchased from Megazyme International Ltd. (Ireland).

B. Grinding Machines

For dry and semi-wet grinding process, a hammer mill (Rotary Type CNS, Taiwan) was used. For wet grinding, hammer mill and stone mill (Wet Grain Grinder, WGG 254, Malaysia) were used.

C. Rice Flour Preparation

Sample was prepared using three different grinding techniques. In the dry grinding technique, the rice grains obtained were directly ground into rice flour for two cycles using the hammer mill. In the semi-wet grinding

Manuscript received June 26, 2015; revised October 22, 2015.

doi: 10.18178/ijfe.1.2.111-114

technique, rice grains were soaked in water for 8 hours at rice to water ratio of 1:1 (w/v). The excess water was then drained and the rice grains were allowed to dry at room temperature before grinding with the hammer mill. In the wet grinding technique, rice grains were ground using stone mill with excess water after subjected to soaking for 8 hours at rice to water ratio of 1:1 (w/v). The slurry obtained was filtered pressed and the semi dried residue was collected. The dried sample was reground using hammer mill. All flour samples were dried in a cabinet dryer to obtain moisture content of less than 15% prior to the analysis. Flour samples were sieved through a 100 mesh sieve (Retsch, Germany) and packed in air tight plastic container until further use.

D. *Proximate Composition*

The moisture, crude protein, fiber, lipid and ash content were determined according to AOAC standard methods [5]. Carbohydrate content was determined by calculation by difference.

E. *Amylose/Amylopectin Content*

The amylose content and starch damage percentage were measured using the assay kit by Megazyme International Ireland. The procedure in amylose content determination involved the modification of a Concanavalin A method developed by [6].

F. *Starch Damage Content*

The damaged starch content in the flour was determined in accordance with the approved method 76-31 of the American Association of Cereal Chemists (AACC) [7]. Calculation of starch damage level following (1):

$$\text{Starch Damage (\%)} = \Delta E \times F/W \times 8.1 \qquad (1)$$

where:
ΔE = absorbance (reaction) read against the reagent blank
F = 150 (µg of glucose)/absorbance of 150 µg of glucose
W = the weight in milligrams ("as is" basis) of the flour analyzed.

G. *Particle Size Distribution*

The particle size distribution and average particle size of rice flour samples were analyzed by using the Mastersizer (Malvern Instrument, UK) fitted with Scirocco 2000 units for the dry samples.

H. *Swelling Power, Solubility and Water Absorption Index*

Flour swelling power and solubility was determined according to the method of [8]. The water absorption index was determined using the method of [9] with some modifications. Flour (2g) was mixed with 30mL of distilled water and heated for 30 min in a water bath at 30 °C. The heated solution was centrifuged (2000 ×g) for 10 min. The sediment was weighed to determine the water absorption index using (2).

$$WAI = \text{Weight of sediment/Weight of dry sample} \qquad (2)$$

I. *Color Measurement*

Color was measured using Colorimeter Minolta (CR-300, Japan). The parameters determined were L* (L*=0 [black] and L*=100 [white]), a* (−a*=greenness and +a*=redness), b* (−b*=blueness and +b*=yellowness).

J. *Statistical Analysis*

Values were expressed as mean with standard deviation of triplicate determinations. Data was analyzed by analysis of variance (ANOVA) using Statistical Analysis System (SAS) software (for Windows V9.13, SAS Institute Inc., Cary, NC, USA) [10].

III. Results and Discussion

Proximate compositions in flours are listed in Table I. The moisture content of all flour samples ranged between 10.37-11.22%, which is within the acceptable range for effective flour storage. Both semi-wet and wet ground rice flours had significantly less proximate constituents of protein, lipid and ash compared to dry ground flour as the soaking process involved in both techniques caused the constituents to leach out from the rice kernel [9]. Carbohydrate content for all flours was more than 75% which indicate good source of carbohydrate in staple diet.

Amylose fraction in the starch component of flours varied between 20.22-20.76%. Based on this result, Malaysian rice variety used in this study was classified as intermediate amylose content rice cultivar [11]. Wet grinding had produced flour with significantly lowest percentage of damaged starch (4.08%). Grinding using stone mill with excess water resulting in the softening of the rice kernels, and the heat generated also being absorbed by the water during grinding, thus reduce the percentage of damaged starch [2].

Different grinding processes have been shown to produce different degrees of damage to starch granules in flour depending on the mechanical forces used during grinding [12]. The hammer mill pressed the grains against an abrasive ring at high rotating speed to break the grain structure, and for dry grinding which lack addition of water to soften the rice kernels, became the reason why dry ground flour exhibit significantly highest percentage of damaged starch (Table II).

TABLE I. PROXIMATE COMPOSITIONS OF DRY, SEMI-WET AND WET GROUND RICE FLOURS

	Moisture	Protein	Fiber	Lipid	Ash	Carbohydrate
Dry grinding	10.37 ± 0.17^b	12.89 ± 0.00^a	0.53 ± 0.02^c	0.26 ± 0.04^a	0.08 ± 0.00^a	79.49 ± 0.16^a
Semi-wet grinding	11.15 ± 0.08^a	10.37 ± 0.01^b	0.64 ± 0.03^b	0.13 ± 0.02^b	0.03 ± 0.00^b	77.68 ± 0.09^b
Wet grinding	11.22 ± 0.32^a	9.26 ± 0.05^c	1.37 ± 0.02^a	0.27 ± 0.01^a	0.01 ± 0.00^c	74.23 ± 0.30^c

[a] Means size values with the same superscript letters within a row are not significantly different at p>0.05.

TABLE II. AMYLOSE AND DAMAGED STARCH CONTENTS OF DRY, SEMI-WET AND WET GROUND RICE FLOURS

	Amylose (%)	Damaged starch (%)
Dry grinding	20.47±0.03^{b}	10.04±0.01^{a}
Semi-wet grinding	20.22±0.01^{c}	4.20±0.04^{b}
Wet grinding	20.76±0.03^{a}	4.08±0.03^{c}

[a] Means size values with the same superscript letters within a row are not significantly different at p>0.05.

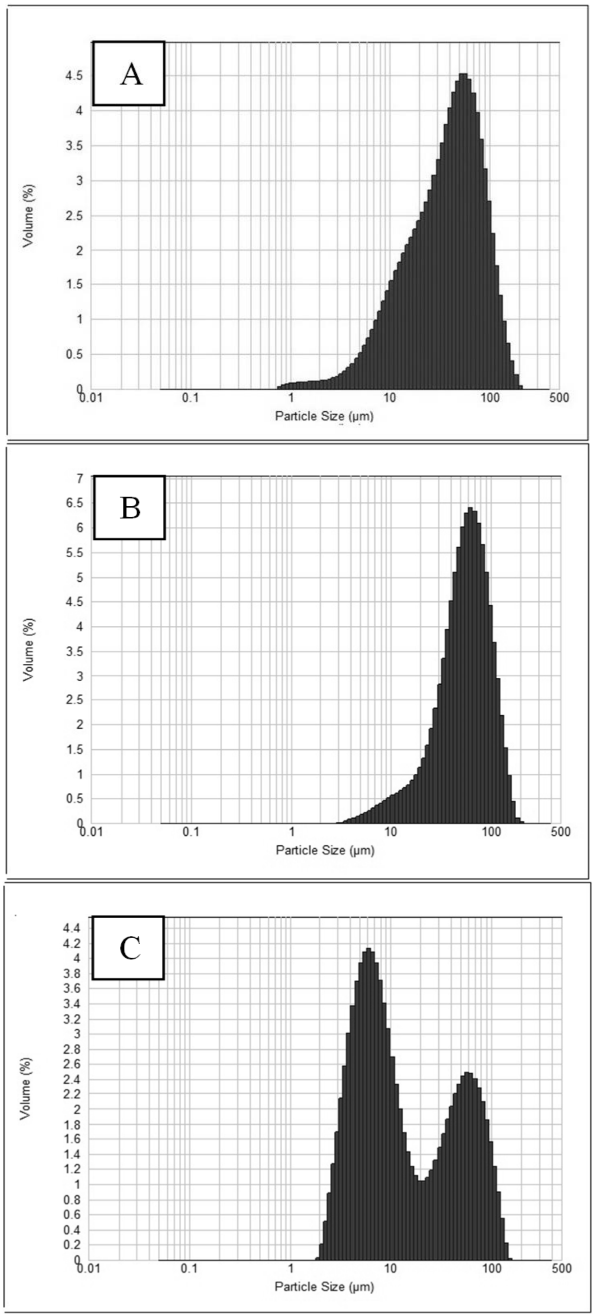

Figure 1. Particle size distribution of dry (A), semi-wet (B) and wet (C) rice flours.

As shown in Fig. 1, it can be clearly seen from the curve obtained that flour for wet grinding process was finer than others. The results also revealed that the wet ground rice flour composed of the finest average particle size (9.32 µm) compared to dry (39.98 µm) and semi-wet (54.28 µm) ground flours. The soaking process of rice kernel involved in wet grinding technique is claimed to affect the flour's particle size distribution [9]. As more water diffused, the rice kernels become softer make it easily broken, thus resulting in small particle granules during grinding process. The results obtained were in agreement with the results reported by [13]. Color of resulting rice flours showed lightness (L*) value was highest using wet grinding technique (Table III). This may due to the fine particle size granules [14]. Nevertheless, the lightness of dry ground rice flour sample (91.72) was comparatively higher than a Korean rice flour (90.00) subjected to dry grinding as reported by [15]. Stone-milled flour also gave the lowest b value. The b value indicated a tendency toward decreasing yellowness.

TABLE III. COLOR ATTRIBUTES OF DRY, SEMI-WET AND WET GROUND RICE FLOURS

	Dry grinding	Semi-wet grinding	Wet grinding
L*	91.72±0.04^{b}	91.45±0.03^{c}	93.55±0.00^{a}
a*	-0.24±0.03^{a}	-0.28±0.02^{b}	-0.23±0.03^{a}
b*	4.45±0.07^{a}	3.87±0.04^{b}	2.81±0.02^{c}

[a] Means size values with the same superscript letters within a row are not significantly different at p>0.05.
L*=lightness (0=black and 100=white), a* (−a*=greenness and +a*=redness), b* (−b*=blueness and +b*=yellowness).

Table IV showed that flour swelling power ranged from 7.77-13.31. Dry ground rice flour indicated highest swelling tendency compared to semi-wet and wet ground flours which might indicate the weak bonding forces within the granules [16]. Meanwhile, flour solubility varied between 0.02-0.06, with significantly highest solubility of dry ground flour due to high severity of milling treatment [17] as compared to semi-wet and wet grinding techniques. Dry ground flour also had significantly highest water absorption index (2.37).

Hatcher *et al.* (2009) [18] claimed that damaged starch will increase the water absorption capacities of flour as damaged starch is able to absorb four to five times more water than intact starch. The grinding process may cause cracking on the starch granule surface, make it easily susceptible for water penetration [19]. Hatcher *et al.* (2009) [18] also claimed that particle size distribution of milled flours affects the rate of hydration during processing, as very fine (<180 µm) particle-sized flours have greater tendency of absorbing more water during hydration.

TABLE IV. WAI, FSP AND FSL OF DRY, SEMI-WET AND WET GROUND RICE FLOURS

	Dry grinding	Semi-wet grinding	Wet grinding
WAI	2.37±0.00^{a}	1.64±0.01^{c}	1.74±0.03^{b}
FSP	13.31±0.18^{a}	7.77±0.16^{c}	10.18±0.06^{b}
FSL	0.06±0.01^{a}	0.02±0.00^{b}	0.02±0.00^{b}

[a] Means size values with the same superscript letters within a row are not significantly different at p>0.05.
WAI = water absorption index, FSP = flour swelling power, FSL = flour solubility.

IV. Conclusion

The three grinding processes involved in rice flour production affects its composition, depending on the method used; and resulting in variation findings in chemical and functional characteristics of rice flours. Based on the results of this research, grinding method to be considered in producing the flour and to be utilized in rice based food products is depending on the specific uses.

Overall, the findings suggest that wet grinding process can be regarded as the potential flour grinding practice since it produces flour with higher amylose content, lowest starch damage, finest average particle size and whiter in color when compared to others. Less damaged starch made the flour had a medium water absorption index and also flour swelling capacity and solubility. Nevertheless, dry grinding process produce flour retaining the most proximate constituents, as rice grains were directly ground into flour that allow minimal losses of nutritive components.

Acknowledgment

The authors thank Universiti Teknologi MARA, Research Management Institute UiTM, Universiti Sains Malaysia and Malaysian Agricultural Research and Development Institute for the support and assistance throughout this research. The Fundamental Research Grants (600-RMI/FRGS) is acknowledged.

References

[1] J. Patindol and Y. J. Wang, "Fine structures of starches from long-grain rice cultivars with different functionality," *Cereal Chemistry*, vol. 79, no. 3, pp. 465-469, 2002.

[2] P. Ngamnikom and S. Songsermpong, "The effects of freeze, dry, and wet grinding processes on rice flour properties and their energy consumption," *Journal of Food Engineering*, vol. 104, pp. 632-638, 2011.

[3] J. Kim, J. Song, and M. Shin, "Physicochemical properties of high amylose rice starches purified from Korean cultivars," *Starch/Starke*, vol. 62, pp. 262-268, 2010.

[4] A. O. Ashogbon and E. T. Akintayo, "Morphological, functional and pasting properties of starches separated from rice cultivars grown in Nigeria," *International Food Research Journal*, vol. 19, no. 2, pp. 665-671, 2012.

[5] Association of Official Analytical Chemists, *Official Methods of Analysis of AOAC International*, 17th ed., Washington DC: AOAC International, 2000.

[6] S. Yun and N. K. Matheson, "Estimation of amylose content of starches after precipitation of amylopectin by concanavalin-A," *Starch/Starke*, vol. 42, no. 8, pp. 302-305, 1990.

[7] American Association of Cereal Chemists, "AACC method 76-31 and 61-02," in *Approved Methods of AACC*, 10th ed., St. Paul, MN: American Association of Cereal Chemists, 2000.

[8] G. B. Crosbie, W. J. Lambe, H. Tsutsui, and R. F. Gilmour, "Further evaluation of the flour swelling volume test for identifying wheats potentially suitable for Japanese noodles," *Journal Cereal Science*, vol. 15, pp. 271-280, 1992.

[9] P. Y. Chiang and A. I. Yeh, "Effect of soaking on wet-milling of rice," *Journal of Cereal Science*, vol. 35, pp. 85-94, 2002.

[10] Statistical Analysis System, *SAS: User's Guide Statistics, (Version 9.13)*, Cary, NC: SAS Institute, Inc., 2002.

[11] International Rice Research Institute. (2007). Procedures for measuring quality of milled rice. *Rice Quality*. [Online]. Available: http://www.knowledgebank.irri.org/

[12] T. T. B. Tran, K. J. Shelat, D. Tang, E. Li, R. G. Gilbert, and J. Hasjim, "Milling of rice grains. The degradation on three structural levels of starch in rice flour can be independently controlled during grinding," *Journal of Agricultural and Food Chemistry*, vol. 59, pp. 3964-3973, 2011.

[13] R. Asmeda, A. Noorlaila, and M. H. Norziah, "Relationships of damaged starch granules and particle size distribution with pasting and thermal profiles of milled MR263 rice flour," *Food Chemistry*, vol. 191, pp. 45-51.

[14] J. J. Chen, S. Lu, and C. Y. Lii, "Effects of milling on the physicochemical characteristics of waxy rice in Taiwan," *Cereal Chemistry*, vol. 76, no. 5, pp. 796-799, 1999.

[15] Y. J. Mo, J. U. Jeung, Y. S. Shin, C. S. Park, K. H. Kang, and B. K. Kim, "Agronomic and genetic analysis of Suweon 542, a rice floury mutant line suitable for dry milling," *Rice*, vol. 6, no. 37, pp. 1-12, 2013.

[16] A. O. Ashogbon and E. T. Akintayo, "Morphological, functional and pasting properties of starches separated from rice cultivars grown in Nigeria," *International Food Research Journal*, vol. 19, no. 2, pp. 665-671, 2012.

[17] E. Li, S. Dhital, and J. Hasjim, "Effects of grain milling on starch structures and flour/starch properties," *Starch*, vol. 66, pp. 15-27, 2014.

[18] D. W. Hatcher, G. G. Bello, and M. J. Anderson, "Flour particle size, starch damage, and alkali reagent: Impact on uniaxial stress relaxation parameters of yellow alkaline noodles," *Cereal Chemistry*, vol. 86, pp. 361-368, 2009.

[19] A. F. Devi, K. Fibrianto, P. J. Torley, and B. Bhandari, "Physical properties of cryomilled rice starch," *Journal of Cereal Science*, vol. 49, pp. 278-284, 2009.

A. Noorlaila is currently an associate professor of Food Science and Technology Programme at Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, Malaysia. She completed her PhD in Food Science at University of Leeds, United Kingdom. Her research interests include physicochemical characteristics, chemical and physical modification of starch, hydrocolloids and starch in processed foods as well as stability of antioxidant in food processing.

R. Asmeda is currently a postgraduate student at Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia. She had completed her study in Bachelor (Hons) in Food Science and Technology. Currently, she is pursuing her study in Doctor Philosophy in Science (Food Science and Technology).

M. H. Norziah is currently a professor of Food Technology Department at Universiti Sains Malaysia, Penang, Malaysia. Her research interests include chemistry/functionality/modification of food biopolymers especially starches (sago and rice), hydrocolloids, development of active packaging materials (edible films and coatings) based on blends of starch and hydrocolloids for shelf-life improvement of food products as well as by-product recovery from fish processing wastes, especially fish gelatin and fish oils.

