J. Trop. Agric. and Fd. Sc. 44(1)(2016): 147 – 155

Characteristics of local rice flour (MR 220) produced by wet and dry milling methods

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Abstract
Rice flour produced by wet milling and dry milling process were evaluated in terms of physical, functional, chemical and nutritional properties. The local paddy variety MR 220 were milled and processed into rice flour. Dry-milled rice flour was produced by dry milling using air-isolating cyclone machine. For wet milling process, the rice was wet cleaning and soaked with water before grinding. The particle size distribution of flour showed that a higher percentage of particles were retained on the smaller meshes. Statistical results indicated that wet-milled flour (L = 92.54) is significantly lighter in colour than dry-milled (L = 97.12). The bulk density ranged between 0.62 – 0.93 g/ml. The moisture contents of flour were in the range of 6.2 – 8.8% wet basis and the water and oil absorption capacity were between 0.7 – 1.2 g/g and 0.5 – 0.8 g/g respectively. Protein and fat contents of dry-milled was significantly higher than those of wet-milled. Both flour had appreciable amount of mineral and vitamin contents. There was also higher degree of starch damage in dry-milled rice flour. Quality evaluation indicated that quality of rice flour varied and may influence by the milling processes.

Key words: rice flour quality, wet-milled rice flour, dry-milled rice flour

Introduction

Rice (*Oryza sativa* L.) is the staple food for the people of Malaysia and will continue to remain in the future. Although it is consumed mainly as a whole grain, some of rice kernels are cracked during harvesting, handling, drying and milling. The amount of broken rice produced is about 15 – 25% of total milled rice. The big broken rice sell for a little more than half the price of whole rice, whereas the smaller fragments sell for less than half of comparable whole grains. Therefore, these smaller pieces are used for grinding into rice flour. Rice flour are produced across a broad range of particle specifications and are classified as grits, coarse medium grain flour, coarse long grain flour, medium flour and fine flour (Becker et al. 2001).

Rice flour is one of the most appropriate cereal flours for consumers with Celiac disease, since there is no gluten in it (Yoengyongbuddhagal and Noomhorm 2002). Developers of new rice foods have recognised the wide diversity in composition and properties of various rice flour. One important feature of rice is its easy digestibility (Kylie 2000).

Article history
Received: 1.11.12
Accepted: 21.10.15

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The relevant literature quotes a digestibility rate of between 98 – 100%, which means that rice starch is one of the most easily digestible starches of all. This digestibility, together with the fact that it is totally hypoallergenic, is one of the main reasons why rice is used so widely in baby food and other special dietary foods. Apart from that, research showed that local rice such as Adan Halus rice, Mas Wangi, MR 219 and MR 220 have low levels of fat, sodium and energy, thus has a bright potential to be promoted as healthy ingredient in health food (Rosniyana et al. 2010).

In Malaysia, wet milling is normally used in rice flour production for rice noodle manufacturing. The process begins with washing and soaking whole or broken rice followed with wet milling. Water is decanted to obtain wet flour after which it is dried in hot air before sieving to desired particle size (Yeh 2004).

Presently, there are two types of commercial rice flour, waxy or glutinous rice and nonwaxy flour, available in the local market. These flours are made from broken milled of long, medium and short grains (Yeh 2004). The commercial rice flour are commonly differentiated by particle distribution specification and medium grain or long grain (Tsai et al. 1997). Large variations in flour performance might exist if the variety mix in the long grain and medium grain classes. Since rice flour is made from broken milled rice, its chemical composition is the same as the whole rice, but there are varietal differences in protein, lipid, starch content and the amylose and amylopectin ratios in the starch. Addition to that, the quality of rice flour may differ according to methods used in producing the flours. Several studies have indicated that the properties of starch present in the rice flour are influenced by various factors, and thus produce rice flour of different physicochemical and functional properties. This work aims to evaluate the quality of rice flour produced by wet milling and dry milling. The quality of both flours is compared with the commercial flour which was bought from the local market.

Materials and methods

Preparation of raw material

MR 220, obtained from MARDI Seberang Prai in Pulau Pinang was used for this study. The paddy was dried and cleaned.

A 2-tonne milling plant situated at MARDI Station, Bukit Raya, Kedah was used to process milled rice on a commercial basis. Paddy at moisture content of 14% was dehusked and polished. Rice flour from milled rice was prepared by dry milling and wet milling. This process was carried out in triplicate. Commercial flour (CF) bought from local market was also used in this study.

Wet-milled flour (WMF)

WMF was prepared with wet cleaning and soaking the rice before milling with a grinder (Yeh 2004). Rice slurry was sieved through a 40 mesh screen before separating water using cheese cloth. Rice lump was broken and dried in an oven at 45 °C for 16 h. Dried flour was finely ground using an electric mill before storing in a sealed plastic bag at room temperature until used.

Dry-milled flour (DMF)

The rice flour was processed by dry milling method using air isolating type grinding machine (Rosniyana et al. 2011). The milled rice was fed at a controlled rate to an impeller chamber, ground and separated into a sample cyclone stream and a bulk or waste cyclone stream.

Chemical analysis

All samples of flour were taken and analysed for moisture, protein, crude fibre, fat, ash, phosphorous, potassium, sodium, calcium, iron, thiamine, niacin and riboflavin. Moisture, protein, fat, and ash were determined using standard AOAC methods (AOAC 1990). Protein was determined by Kjeldahl nitrogen method using Kjeltec system 1026 (Tecator 1978).

Fat was determined by Soxhlet extraction and ashing was done at 550 °C to constant weight. Determination of crude fibre was carried out by Weende method using fibretec system (Tecator 1978).

Physical and physio-chemical properties

Physical and physico-chemical properties of rice flours that were determined include particle size, colour, bulk density, moisture content, starch damage, gel consistency, gelatinisation temperature, amylose content, solid loss, water absorption capacity and oil absorption capacity of rice flour. All analyses were carried out in two replicates. Particle size analysis was carried out to determine the size distribution of flour particles to ensure consistent particle size. The procedure was carried out on a Rotap device (Endocott test sieve shaker, London, England) with six screens ranging from mesh no. 20 – 120. The unit was shaken for 5 min. Minolta Chroma Meter Test was used to measure colour of flour. A sample of flour was placed on the granular attachment materials attachment and compacted. Flour colour results were reported in the term of 3-dimensional values based on the CIE 1976 L*a*b* colour syatem.

Duplicate readings of moisture content of rice flour were determined by using AOAC Official Methods (AOAC 1990). Triplicate readings of bulk density of flour were determined (Kim and Teledo 1987). A known weight of the flour was added to a graduated measuring cylinder. The cylinder was gently tapped and volume occupied by the sample was determined. Bulk density was reported as weight per unit volume (g/ml).

Water and oil absorption capacity was determined according to modified method as described by Tsai et al. (1997). Sample (0.5 g) was taken and mixed with 3 ml of distilled water or refined groundnut oil. The slurry was centrifuged at 750x g for 15 min. The pellet was drained for 30 min and the gain in weight per unit weight was reported as water or oil absorption capacity (g/g), respectively.

Amylose content was estimated by the iodine binding capacity method of Malaysian Standard developed by SIRIM, Rice – Determination of Amylose Content, MS ISO 6647:1998 as refer red to AACC. The gelatinisation temperature was estimated from alkali spreading value of 10 rice grains soaked in 15 ml of 1.7% KOH for 23 h at room temperature (Little and Hilder 1958). Starch damage was determined using the AACC 76-31 (AACC 1995) with the damaged starch assay kit from megazyme. The gel consistency was determined based on the length of cold horizontal gel expressed in mm in a 13 mm x 100 mm test tube according to the method of Cagampang et al. (1973). The rice samples were classified as hard (26 – 40 mm), medium (41 – 60 mm) or soft (61 – 100 mm). Total solid loss was determined from the residues of 10 ml cooking liquid after drying at 100 °C for 2.5 h.

Statistical analysis

For this study, flour was produced in two replicates. All determinations were statistically analysed by the analysis of variance and mean values are presented. The Duncan multiple range test was used to detect differences between treatments (Gomez and Gomez 1984).

Results and discussion

Chemical composition

Chemical composition varied significantly among three types of flour (WMF, DMF and CF) are shown in *Table 1*. The moisture content of these flours ranged from 7.2 – 8.8% which was below 13%, which is good for maintaining flour quality (Naivikul 2004). Even though the moisture content of the flour was comparatively high, it did not promote microbial spoilage, therefore storability at room temperature was not a problem. The low level of moisture content can be easily achieved after effective processing processes, i.e. drying/baking/

Table 1. Chemical compositions of rice flour

% (wet basis)	Dry-milled rice flour	Wet-milled rice flour	Commercial rice flour
Moisture (%)	7.2b	8.8a	8.4a
Fat	0.34 ± 0.05a	0.18 ± 0.25c	0.21 ± 0.25b
Protein	8.85 ± 0.75a	7.2 ± 0.75b	7.6 ± 0.75b
Crude fibre	0.42 ± 0.05a	0.38 ± 0.10b	0.34 ± 0.10b
Ash	0.7 ± 0.25a	0.56 ± 0.05b	0.52 ± 0.05b
Carbohydrate	89.69 ± 0.05a	91.68± 0.25a	91.33 ± 0.25a
Starch damage (%)	8.1a	5.4a	7.2b
Amylose (%)	20.8b	22.1a	21.2b

Data were expressed as mean ± SD, each value is a mean of duplicate readings
Means followed by a different letter with the same row are significantly different (p <0.05)

toasting and packing in good moisture barrier packaging materials.

Carbohydrate is the major constituent of rice and present in the range of 89.69 – 91.68 %. Amylose content of dry-milled flour was significantly lower than that of wet-milled rice starch. As shown in latter results, dry-milled flour had higher in finer flour than wet-milled flour which may indicate that dry milling process which cause more mechanical damage may influence the structure of starch with led to more damaged starch. It is suggested that the amylose content may be reduced due to this grinding step in the dry-milling process. This result agrees with Nishita and Bean (1982), who studied grinding impact on rice flour properties, found finer flour have higher level starch damage.

Protein and fat contents of dry milled flour were significantly higher than those of wet-milled flours. Due to the wet-milling process, rice kernel had to be soaked and grinded with water. Soluble proteins, sugars and non-starch bound lipids are removed, resulting in lower amount of these matters in wet-milled flours (Debet and Gidley 2006). This is further discussed in the section of solid loss. Fat is located in various parts of rice kernel, therefore, method of milling could affect lipid content (Hoseney 1998). Even if the fat content in flours was low, it could affect flour properties dramatically such as swelling and pasting properties.

The various mineral compositions in the flour are presented in *Table 2*. The major mineral in the product was phosphorus (72 – 84 mg/100 g). Potassium was present within a range of 46 – 72 mg/100 g sample, while magnesium was 15 – 29 mg/100 g sample. The level of iron in rice flour was 0.6 – 1.1/100 g and is of considerable low (Tee et al. 1997). The results indicated that methods of milling may influence the mineral contents and resulted higher in mineral contents for dry-milled flour. It is suggested mineral may leach out during washing and soaking of rice grain.

According to Malaysian Food Regulations, the levels of vitamins were generally low and had no distinct trend (*Table 2*). Rice flour was found to have appreciable amount of retinol. The thiamine content was considered low, varied from 0.08 – 0.20 mg/100 g. Similarly with riboflavin level, the range varied between 0 – 0.01 mg/100 g. Pyridoxine varied from 0.22 – 0.6 mg/100 g sample. The niacin levels were low which contained 1.2 – 3.0 mg/100 g sample.

Physical and physio-chemical properties

Physical properties of rice flour (WMF, DMF and CF) include particle size, colour, bulk density, moisture content, gel consistency, water absorption capacity and oil absorption capacity of rice flour (*Tables 3 – 4*). Particle size distribution of rice flour for processing is important

Table 2. Mineral and vitamin contents of rice flour (mg/100 g)

	Dry-milled rice flour	Wet-milled rice flour	Commercial rice flour
Calcium	5.1 ± 0.5a	4.2 ± 0.25b	3.4 ± 0.5c
Iron	1.1 ± 0.2a	0.8 ± 0.0b	0.6 ± 0.5b
Magnesium	28.5 ± 0.1a	15.1 ± 0.1b	16.8 ± 0.1b
Sodium	0.8 ± 0.75a	0.8 ± 0.1a	0.70 ± 0.1a
Potassium	72 ± 0.25a	65 ± 0.5b	46 ± 0.5c
Phosphorus	84 ± 0.75a	72 ± 0.5b	34 ± 0.5c
Thiamine	0.2 ± 0.75a	0.15 ± 0.01a	0.08 ± 0.01b
Riboflavin	0.01 ± 0.25a	–	–
Pyridoxine	0.60 ± 0.25a	0.32 ± 0.1b	0.22 ± 0.5c
Niacin	3.0 ± 0.05a	1.2 ± 0.5a	1.4 ± 0.1a

Data was expressed as mean ± SD, each value is a mean of duplicate readings
Means followed by a different letter with the same row are significantly different (p <0.05)

because it provides consistency in material specification. In addition to that, particle size distribution determines the percentage frequency of distribution of particles size (Lachman et al. 1986). Particle distribution of rice flour of DMF showed that less than 5% was retained on mesh 20 – 100. About 95.07% of the particle was retained on mesh no. 120 indicating more fines were produced. Weight fraction of smallest particles was the highest than the other fraction in DMF. Results suggested that using cyclone mill would probably cause flour of the smaller size particle. As compared to DMF, the particle size distribution of WMF and CF had higher percentage of the smallest particle retained on the bottom meshes, and about 44% retained on mesh 120 indicating less fine particles were found in CF. Particle size distribution is one the important physical characteristics that affecting the properties and application of flour (Chen et al. 1999). Fine rice flour is used in the manufacture of baby food, baked products, bulking agents and flavour carriers. Coarse rice flour is used as a cereal binder for small goods because it has a high water holding capacity and to make snack foods.

The bulk density of flours showed that the finest flour DMF, was 0.62 g/ml, whereas the WMF, the coarser flour was higher (0.93 g/m). These indicated that the coarse flour was heavier than the finer flour. The low bulk density of DMF was due to its lower particle density and the large particle size (Oladele and Aina 2007). Bulk density is a measure of heaviness of flour. According to Onimawo and Egbekun (2002), bulk density is an important parameter that determines the packaging requirement of a product and signifies the behaviour of a product in dry mixes. Also, it varies with the fineness of the particles. High bulk density is disadvantageous for the formulation of weaning foods, where low density is required.

Colour measurement showed that finer flour has whiter and brighter in colour. The results indicated that wet-milled rice flour (L = 92.54) is less lighter in colour than dry-milled rice flour (L = 97.12). Statistically, it was found that the colour of wet-milled rice flour did differ significantly from the colour of dry-milled flour. The results indicated that the sample particle size affected the colour, and that the smaller flour particles resulted in a smoother surface. Study by Mok and Dick (1991) has indicated that that finer flour was brighter. Flour colour often affects the colour of the finished product, and is therefore one of the many flour specifications required by end-users. Generally speaking, bright white color flour is more desirable for many products.

Table 3. Percentage of different particle size of rice flour

Mesh sieve size	Particle size (mm)	Dry-milled rice flour	Wet-milled rice flour	Commercial rice flour
20	0.850	0.28 ± 0.05f	0.12 ± 0.25e	0
30	0.600	1.52 ± 0.05e	0.59 ± 0.05d	2.21 ± 0.05e
50	0.300	12.50 ± 0.05d	0.60 ± 0.15d	5.23 ± 0.15d
80	0.180	27.35 ± 0.05b	2.89 ± 0.25b	19.55 ± 0.05c
100	0.150	25.71 ± 0.15c	0.76 ± 0.05c	28.83 ± 0.05b
120	0.125	32.66 ± 0.15a	95.07 ± 0.15a	44.18 ± 0.05a

Data were expressed as mean ± SD, each value is a mean of duplicate reading
For each flour, means followed by a different letter with the same column are significantly different ($p < 0.05$)

Table 4. Physical and functional properties of rice flour produced from different type of milling

	Dry-milled rice flour	Wet-milled rice flour	Commercial rice flour
Bulk density (g/ml)	0.62c	0.93a	0.87b
Colour			
L* (lightness)	97.12a	92.54b	93.10b
a* (red to green)	–4.97a	–4.85a	–5.10a
b* (yellow to blue)	7.39a	6.92a	7.2a
Gelatinisation temperature (Group)	High	Medium	High
Gel consistency (mm/Group)	Soft	Medium	Hard
Water holding capacity	1.2a	0.71b	0.88a
Oil holding capacity	0.8a	0.58b	0.5b
Solid loss	4.2b	5.8a	4.7b

Data were expressed as mean ± SD, each value is a mean of duplicate reading
Means followed by a different letter with the same row are significantly different ($p < 0.05$)

Rice contains starch granules which can be cracked or broken during the flour milling process. Damaged starch is the portion of starch granules that was mechanically disrupted during the process of extract or refines flour (Hatcher et al. 2002). Results showed that damaged starch for DMF is found higher than WMF. This may relate that starch damage content was high in finer flour (DMF) and was directly related to solid loss and swelling capacity. These results indicated that dry-milling process caused more mechanical damaged to the starch granules than wet-milling process. This result agree with Nishita and Bean (1982), who studied grinding impact on rice flour properties, found that the finer flour has a higher level of starch damage. Hatcher et al. (2002) studied the effect of difference wheat flour size on damaged starch also found that the damage starch decreased with increase in flour particle size. Damaged starch is important for flour properties, whereby flour of higher damaged starch is more susceptible to degradation by enzymes activities.

Flour produced by dry-milling process had high gelatinisation temperature (GT) while intermediate GT was found in WMF. Previous study by Lai (2001) had indicated that flours containing high amylose content had higher gelatinisation parameters. This may be due to the rigid amorphous regions of the starch granule by the interaction among amylose chains. The stability of amorphous region may be increased, resulting in higher energy for gelatinisation and gelatinisation temperature. Accordingly, results indicated that DMF with high gelatinisation temperature remained largely unaffected or partial disintegration at low temperature and takes a longer time for the starch to swell.

Flour produced by dry-milling process has soft gel while commercial flour and flour produced by wet milling process has hard and medium gel respectively. Results suggested that the soft gel of rice flour was due to the presence of smaller particles and higher percentage of damaged starch. Flour with high percentage of damaged starch had non-uniformed size of starch granule resulted in weak gel which can easily break (Aichyawanich 2002). Since damaged starch in flour is the cause of losing intact gelatinised starch granule structure and fragmentation of amylopectin in starch molecule, the structure of flour gel with higher percentage of damaged starch formed non-tighten network structure which can easily loose.

The water absorption capacity of the DMF, WMF and CF were 1.2, 0.71 and 0.88 g/g respectively and were significantly different (p <0.01). Earlier results had showed that, it was observed that DMF with more fine particles will have higher water uptake than WMF and CF. According to Chen et al. (1999), the smaller particle surface area of flour is easily hydrolysed by enzyme, and thereby allowing particles to absorb water at higher rate. Other finding has showed that the finer flour swelled to higher extend than coarse flour indicating that weaker starch granules in finer flour than coarse flour. This was caused by the higher starch damage that occurs in finer flour since disruption of the crystalline structure in flour allowed permeation by water on the whole granules (Grant 1998). Oil absorption capacity (OAC) of DMF, WMF and CF were significantly difference with the values of 0.8, 0.58 and 0.5 g/g respectively. The higher OAC of DMF could also due to its protein and fat contents which can entrap more oil. According to Chen et al. (1999) the hydrophobicity of proteins plays a major role in oil absorption.

For solid loss values, there was higher soluble matter measured from DMF compared with those of WMF. These results indicated that higher degree of starch damaged occurred during dry-milling process than that of wet-milling caused larger water permeation into starch granules and greater soluble matter comes out from starch granule (Chen et al. 1985).

Conclusion

Quality analysis of rice flour samples indicated that some differences existed in the chemical, nutritional, physical and physio-chemical properties characteristics of rice flour produced by wet-milling and dry-milling process. Dry-milled flour is whiter than wet-milled flour and commercial flour and has soft gel. Dry-milling process produced higher starch damaged in the flour and study indicated that the solid loss, water holding capacity and oil holding capacity were affected by starch damaged. The gelatinsation temperatures and amylose contents of flour samples differed. These findings gave some indications that the suitability of DMF and WMF for product development may vary and accordingly, the study gives knowledge to food processor in order to produce products of consistent quality.

Acknowledgement

The authors would like to thank Ms Meriam Harun, Ms Hadijah Bakar and Mr Mohamad Tahir Abd. Ghani for their technical assistance.

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Abtrak

Tepung beras yang dihasilkan secara pengisaran basah dan kering dinilai dari segi ciri ciri fizikal, berfungsi dan kimia. Beras varieti MR 220 telah digunakan. Padi dikisar di kilang untuk penghasilan tepung. Tepung beras dari keadah kering dihasilkan dengan menggunakan mesin pengisar tepung jenis *air–isolating cyclone*. Bagi kaedah basah, beras dibersihkan dan direndam sebelum dikisar. Taburan saiz partikel menunjukkan peratusan lebih tinggi partikel tertahan di atas jaringan yang lebih besar. Keputusan statistik menunjukkan tepung daripada kaedah basah (L = 92.54) menghasilkan tepung ketara putihnya daripada keadah kering (L = 97.12). Ketumpatan pukal antara 0.62 – 0.93 g/ml. Kandungan lembapan tepung adalah pada 6.5 – 8.9% dan kapasiti pemegang air dan minyak adalah masing-masing antara 8 – 1.2 g/g dan 0.5 – 0.8 g/g. Kandungan protein and lemak bagi tepung kisar kering adalah ketara tinggi daripada tepung yang dikisar secara kaedah basah. Mengikut nilai kanji rosak, tepung kisar secara kering adalah tinggi berbanding dengan tepung kisar secara basah. Penilaian kualiti menunjukkan mutu tepung beras berbeza dan ini dipengaruhi oleh keadah mengisar seperti pengisaran basah dan pengisaran kering.