

Effects of milling degree on the chemical composition, physico-chemical properties and cooking characteristics of brown rice

(Kesan darjah pengilangan terhadap kandungan kimia, ciri fiziko-kimia dan sifat memasak beras perang)

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Abstract

Brown rice variety, Q34 was milled at different milling degrees (MD) namely 4, 6 and 8% to produce partially milled and milled rice. The proximate content as well as the effect of different MD on nutritional content, physico-chemical and cooking characteristics of brown rice were studied. The chemical composition of brown rice was significantly affected by the milling process. Among the rice evaluated, brown rice milled at 8% MD had the lowest protein, fat and crude fibre content. The highest mineral and vitamin contents were in brown rice followed by brown rice milled at 4, 6 and 8% MD. This indicated that brown rice and partially milled rice offer healthier benefits than milled rice. Milled rice (8% MD) had the highest values for elongation ratio, volume of expansion, water uptake ratio and solid loss. Brown rice took longer time (28 min) to cook which significantly differed from the cooking time of partially milled and milled rice.

Introduction

The mature rice grain is harvested as a covered grain (paddy), with the caryopsis enclosed in a tough siliceous hull or husk (Juliano and Bechtel 1985). The caryopsis itself is a single-seeded fruit, wherein the pericarp is fused to the seed. The hull, seed coat, nucellus, aleurone, endosperm and germ are the principle component of paddy seed. Dehulling separates the husk to produce brown rice.

Brown rice is the unmilled rice containing the pericarp, the seed coat and nucellus, the germ or embryo and the endosperm (Ajimilah and Rosniyana 1995). The seed coat exists in various shades of brown, red and black. During milling, the maternal tissues are removed to produce

milled or polished rice and by-products bran and smaller polish rice. The bran contains more of the pericarp, seed coat, nucellus, aleurone layer, and germ than the polish, which contains relatively starchy endosperm. The bran and the germs are rich in protein, lipids, vitamins and trace minerals. The B-vitamins and α -tocopherol (vitamin E) are concentrated in the bran layers with the embryo accounting for more than 95% of total tocopherols.

Most rice is consumed as polished rice. Among the nutrients often found deficient in diets of rice-eating people, vitamin B₁ and lysine are the most significant because their contents in the milled rice are too low to meet nutritional requirement. Undermilled or home-pounded rice is still consumed in

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some developing regions, but consumption of brown rice is relatively uncommon. As living standard is elevated, people tend to consume more highly refined foods because of their perceived improved palatability and for convenience of preservation and transportation (Eggum 1979).

Rice milling for manufacture of foods may bring about alterations in the chemical composition in a number of ways (Kent 1983). The various nutrients may be distributed non-uniformly throughout the various parts of the grain, so that when separation is made, certain nutrients are preferentially lost. Milling of brown rice at various stages produces milled rice of varying quality (partially milled rice) in accordance to the predetermined degree of milling. Milling degree is generally defined as the extent or degree of removing the different bran layers which cover the grain as a result of polishing (Webb 1985). During whitening process, the outer bran is removed leaving the core component of mostly carbohydrate. However, milling of rice changes the composition and certain nutrients are significantly reduced which may create nutritional hazard.

The physico-chemical properties of rice are subjected to chemical content variability (Juliano 1985a). As this content is removed during milling, the physico-chemical properties of rice at different milling degrees may vary. The physico-chemical criteria have been invaluable for evaluating many aspects of rice cooking qualities. These criteria are based on the series of physico-chemical test, which include amylose content, gelatinization temperature, and gel consistency. Water absorption, volume expansion and solid loss during cooking are directly affected by amylose content while time required for cooking is determined by gelatinization temperature.

The main objective of this study was to assess the effect of milling degree on the chemical and nutritional content of brown rice. It also reported the cooking characteristics of brown, partially milled and

milled rice. This information can be utilized for development of rice products.

Materials and methods

Processing of brown rice, partially milled rice and milled rice

A 2-tonne rice milling plant situated at MARDI Station, Bukit Raya, Kedah was used to process brown, partially milled and milled rice on a commercial basis. The paddy used to produce the three types of rice was a high quality locally developed rice variety Q34 and the production of the rice was carried out in duplicate.

Paddy at a moisture content of 14% (w.b.) was dehusked by a rubber roll huller. The mixture comprising brown rice and paddy was separated by a paddy separator. Brown rice, consisted of head rice and broken grains, was conveyed to the rotary sifter and indented cylinders to separate the broken grains. The damaged, discoloured and immature grains in the head rice were removed by passing the grains through a colour sorter.

The brown rice obtained from the paddy separator was milled by a horizontal abrasive whitener, model Satake according to method developed by Wahid et al. (1997). Through adjustments of a steel weight-load and flow rates, partially milled rice at 4% and 6% milling degrees (MD) were obtained. Well-polished rice (milled rice) was also produced through the adjustment of 8% MD. The rice was conveyed to the rotary sifter and indented cylinders to separate the broken grains.

Physico-chemical analysis

Duplicate samples of brown, partially milled and milled rice 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 1984). Protein was determined by Kjeldahl nitrogen method using Kjeltac system 1026. Fat was determined by Soxhlet

extraction and ashing was done at 550 °C to constant weight. Crude fibre was determined by Weende method using fibertec system (Tecator 1978). Minerals and vitamins were analysed by an accredited company Edtech Associates Sdn. Bhd. according to the method by AOAC (1993). Each analysis was carried out in duplicate. Carbohydrate was calculated by subtracting the values of moisture, protein, crude fibre, fat and ash, from 100.

The amylose content was determined according to simplified assay method as described by Juliano (1972). The gelatinization 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). 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).

Cooking qualities

The cooking characteristics were determined by boiling 8 g of rice in a cylindrical wire basket of 43.5 mm in diameter and 98 mm in length following the small scale cooking method (Juliano 1982). Water uptake was calculated from the ratio of the weight of cooked rice to that of raw rice. Volume of expansion was recorded as a ratio of the

weight of the cooked rice to that of raw rice. Total solid was determined from the residues of 10 ml cooking liquid after drying at 100 °C for 2.5 h.

The cooking time for milled rice was also estimated according to the method of Juliano (1982). The elongation ratio of presoaked rice after cooking was estimated based on the length of 10 cooked and raw kernels, according to the method of Juliano and Perez (1984).

Data analysis

The data were statistically analysed by the Analysis of Variance. The Duncan Multiple Range Test was used to detect differences between samples (Gomez and Gomez 1984).

Results and discussion

Proximate and nutritional composition

Carbohydrate is the major constituent of rice and was present in the range of $78.25 \pm 0.05\%$ to $81.31 \pm 0.30\%$ (Table 1). Carbohydrate in rice is mainly starch and it makes 80% of the rice endosperm (Kent 1983). The concentration of non starchy carbohydrate is higher in the bran and germ fractions than in starchy endosperm. Pascual and Juliano (1983) indicated that the bran layer is high in cellulose and hemicellulose contents which made up the thick cell wall of the pericarp, the seed coat and the aleurone layer. Accordingly, partially milled and milled rice produced at different MD

Table 1. Proximate composition of rice variety, Q34 at different milling degrees

| Composition (% wet wt. basis) | Milling degree (%) | | | |
|----------------------------------|--------------------|------------------------------|------------------------------|--------------------|
| | 0 (Brown rice) | 4 (Partially milled rice) | 6 (Partially milled rice) | 8 (Milled rice) |
| Moisture | 10.50 ± 0.80a | 10.76 ± 0.05a | 10.91 ± 0.05a | 10.25 ± 0.35a |
| Protein (NX5.95) | 8.80 ± 0.10a | 8.76 ± 0.01a | 8.58 ± 0.05a | 8.25 ± 0.05a |
| Fat | 1.80 ± 0.0a | 1.12 ± 0.01b | 0.67 ± 0.25c | 0.39 ± 0.01d |
| Ash | 0.86 ± 0.03a | 0.69 ± 0.03b | 0.45 ± 0.03c | 0.40 ± 0.03c |
| Crude fibre | 0.68 ± 0.02a | 0.50 ± 0.02b | 0.48 ± 0.25c | 0.40 ± 0.02c |
| Carbohydrate* | 78.25 ± 0.05a | 78.77 ± 0.25a | 79.97 ± 0.05b | 81.31 ± 0.30c |

*Calculated by difference

Mean values in the same row with different letters are significantly different using DMRT with $p < 0.05$

had significantly lower crude fibre content than brown rice.

Brown rice had the highest percentage of protein content (8.80 ± 0.10). However, no significant differences were detected in protein content for all rice. Thus, protein content was not affected by MD and this was also reported by Bechtel and Juliano (1980). They stated that the protein was found in the endosperm and it exists as discrete particles located among starch granules. Furthermore, the differences in protein content were more evident in the polish and subaleurone fraction than in the bran.

The fat content was found higher in brown rice (1.80 ± 0.0) than in partially milled and milled rice. It was observed that, the fat content decreased significantly as the milling degree increased. Similar observation was reported by Fujino (1978), and he stated that the degree of milling and the milling procedure influence the content of milled rice as well as bran. In another report by Houston and Kohler (1970), the major proportion of fat is present in bran and embryo. Thus, during milling most of the fat is removed with the bran and polish.

Milled rice contained the lowest amount of minerals (Table 2). The ash distribution in brown rice is reported to be 51% in bran, 10% in germ, 11% in polish and 28% in milled rice (Resurreccion et al. 1979). Other study had indicated that, most

minerals showed a distribution similar to that of total ash (Juliano and Bechtel 1985). More minerals were present in the aleurone and outer layers of the rice kernel than towards centre, thus milling would give a lower amount of minerals in milled rice. Hence, higher amount of minerals was present in brown rice than in partially milled and milled rice.

The highest vitamin content was found in brown rice followed by partially milled rice and milled rice. A major proportion of these vitamins were located in the aleurone layers and the embryo. The vitamin content was significantly reduced during milling because abrasive milling removes the pericarp, seed coat, testa, aleurone layer and embryo which results in loss of vitamins (Juliano 1993).

The physico-chemical properties

Gel consistency is a useful index for softness of cooked rice. The test was conducted to determine the tendency of cooked rice to harden upon cooling. From the study, it was found that the milled rice of Q34 had a medium gel. However, both partially milled and brown rice, which had a hard gel, showed significant decrease in the gel consistency as compared to milled rice. Perez (1979) reported that the fat content had an effect on the gel consistency, probably caused by the formation of an amylose-fatty acid complex. The higher fat

Table 2. Mineral and vitamin compositions of rice variety, Q34 at different milling degrees

| Properties (mg/100 g) | Milling degree (%) | | | |
|--------------------------|--------------------|------------------------------|------------------------------|--------------------|
| | 0 (Brown rice) | 4 (Partially milled rice) | 6 (Partially milled rice) | 8 (Milled rice) |
| Phosphorus | 201.00 \pm 3.00a | 191.41 \pm 0.25b | 160.8 \pm 0.50c | 108.50 \pm 4.50d |
| Potassium | 58.50 \pm 0.50a | 52.65 \pm 0.7b | 46.00 \pm 0.25c | 35.00 \pm 1.00d |
| Sodium | 53.00 \pm 0.00a | 50.86 \pm 0.68b | 40.69 \pm 0.01c | 20.50 \pm 0.50d |
| Calcium | 49.00 \pm 1.00a | 47.00 \pm 0.20a | 32.9 \pm 0.10b | 10.9 \pm 0.90c |
| Iron | 6.05 \pm 0.25a | 4.81 \pm 0.72b | 2.95 \pm 0.10c | 1.60 \pm 0.10d |
| Thiamine | 0.35 \pm 0.01a | 0.30 \pm 0.01a | 0.22 \pm 0.25b | 0.16 \pm 0.02c |
| Niacin | 5.50 \pm 0.10a | 4.80 \pm 0.25b | 3.82 \pm 0.01c | 3.45 \pm 0.05c |
| Riboflavin | 0.16 \pm 0.10a | 0.14 \pm 0.01a | 0.09 \pm 0.05b | 0.07 \pm 0.10c |

Mean values in the same row with different letters are significantly different using DMRT with $p < 0.05$

content found in the outer layers of the rice grain (bran and aleurone) may result in low values in gel consistency of brown and partially milled rice. This indicated that, the degree of milling is a very important factor affecting gel consistency.

The amylose/amylopectin ratio of milled rice determined the properties of cooked rice. It is usually expressed as a percentage of milled rice dry weight rather than as starch basis. Amylose content may be classified as low (10–20%), intermediate (20–24%) or high (>25%). The mean amylose content of Q34 milled rice was 24.4%. The amylose content in brown rice was significantly lower than in partially milled and milled rice. This may be due to the presence of bran layer which contributed to higher dry weight of the grain. Removing the bran at different milling degrees in both partially milled and milled rice had significantly increased the amylose content.

Another property of starch, which is also important in characterizing the rice varieties, is gelatinization temperature. Gelatinization temperature is defined as the temperature at which all the starch granules in a sample lose their birefringence. Results indicated that the milled rice of Q34 had intermediate gelatinization temperature. However, the gelatinization temperature was significantly increased in brown and partially milled rice. Juliano and Perez (1983) made similar observations, and stated

that gelatinization temperature probably reflects the relative porosity of whole endosperm. Marshall et al. (1989) reported that cracking of rice kernel during milling process could also increase the population of starch granules highly accessible to water. Thus, kernel cracking led to additional 1–4 °C decrease in gelatinization temperature. Other study indicated that the fat itself played a role in affecting starch gelatinization in brown rice (Champagne et al. 1990). The greater the degree of milling, the higher the percentage of lipid removed from the kernel and the greater the decrease in gelatinization temperature. They also suggested that fat removal by milling process provides easier water access to starch granules.

Cooking characteristics

A significant reduction trend in cooking time was observed with increasing degree of milling (Table 3). Milled rice had shorter cooking time (15 min) than partially milled (18.8–23.3 min) and brown rice (28.18 min). Sabularse et al. (1991) suggested that this may be attributed to starch fragmentation and opening up of kernel structure by milling, resulting in increased water absorption by rice kernel. Other study stated that the cooking times for milled rice were shorter than for brown and partially milled rice, because of the absence of bran layer which deters water absorption (Juliano

Table 3. Physico-chemical and cooking properties of rice variety, Q34 at different milling degrees

| Properties | Milling degree (%) | | | |
|---------------------------------|--------------------|------------------------------|------------------------------|--------------------|
| | 0 (Brown rice) | 4 (Partially milled rice) | 6 (Partially milled rice) | 8 (Milled rice) |
| Amylose content (%) | 21.80 ± 0.50 | 22.25 ± 0.25 | 23.00 ± 0.25 | 24.4 ± 0.50 |
| Gelatinization temperature (°C) | High | High | High | Intermediate |
| Gel consistency (mm) | 28.55 ± 0.35 | 33.25 ± 0.50 | 33.75 ± 0.35 | 43.80 ± 0.50 |
| Elongation ratio | 1.24 ± 0.25d | 1.63 ± 0.75c | 1.73 ± 0.50b | 1.84 ± 4.50a |
| Cooking time (min.) | 28.18 ± 0.50a | 23.30 ± 0.25a | 18.80 ± 0.25 | 15.00 ± 1.00c |
| Volume of expansion | 3.51 ± 0.75c | 4.30 ± 0.50b | 4.32 ± 0.01b | 4.80 ± 0.50a |
| Water uptake ratio | 2.61 ± 0.35c | 3.14 ± 0.20b | 3.80 ± 0.10a | 3.90 ± 0.50a |
| Solid loss | 0.48 ± 0.25b | 0.45 ± 0.20b | 0.44 ± 0.10b | 0.56 ± 0.10a |

Mean values in the same row with different letters are significantly different using DMRT with $p < 0.05$

1985b.) The differences in the cooking time of brown and milled rice may also be related to differences in starch gelatinization temperature (Juliano and Perez 1983). Rice starch with higher gelatinization temperature has been shown to require longer cooking time than those with lower gelatinization temperature. Binding of fat to amylose and amylopectin may also result in higher gelatinization temperature.

Some varieties expand in size more than others upon cooking. Results showed that all rice had an elongation ratio lesser than 2, suggesting that these rice were not elongated during cooking. However, there was an increasing trend in elongation ratio with increasing degree of milling. The observations suggested that the presence of bran had significantly influenced the elongation ratio of brown and partially milled rice.

In terms of volume of expansion, both brown and partially milled rice differed significantly from milled rice. Milled rice (8% MD) produced higher volume expansion (4.80) than brown and partially milled rice. This indicated that the pericarp and seed coat provided a barrier that controlled water penetration to the starch granules.

Milled rice had the highest water uptake ratio (3.90). Water absorption of brown rice (2.61) was significantly reduced in comparison to partially milled and milled rice because of the presence of wax presumably located in the seed coat and pericarp (Juliano 1985b). According to Juliano (1993), this layer around the starch granule serves as a physical barrier to water absorption. Also, the decrease in water uptake has been attributed to the increase in brown rice hardness.

Milled rice had the highest solid loss (0.56) compared to partially milled and brown rice (0.44–0.48). The solid loss presence in the cooking gruel depends on the solubility of starch content in the rice and it is stated by Juliano that starch in cooking liquid is correlated with amylose

content of the grain. Accordingly, brown and partially milled rice which had lower amylose content has significantly lower solid loss. This is in agreement with the study conducted by Bhattacharya and Sowbhagya (1971) and they also stated that the amylose content of starch that leached into cooking water is influenced by the physical form of rice samples.

Conclusion

Different milling degree significantly affected the chemical and nutritional properties of rice. Generally, these properties decreased as the milling degree increased. Brown rice is highly nutritious rice being high in fibre and provides most of the vitamins and minerals. Variations in amylose content and gelatinization temperature between rice at different milling degrees produced rice of different cooking properties. Brown rice with higher gelatinization temperature seemed to require a little longer time to cook compared to milled rice. The values for water uptake, volume of expansion and solid loss increased as the degree of milling increased.

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Abstrak

Beras perang varieti Q34 telah dikisar pada darjah pengilangan (DP) berbeza iaitu 4, 6 dan 8% bagi menghasilkan beras separa kisar dan beras kisar. Kandungan proksimat serta kesan DP terhadap kandungan nutrien, ciri fiziko-kimia dan sifat memasak beras perang telah dikaji. Kandungan kimia beras perang dipengaruhi dengan ketara oleh DP. Antara beras yang dinilai, beras perang yang dikisar pada 8% DP, mempunyai kandungan protein, lemak dan serabut yang terendah. Beras perang mempunyai kandungan galian dan vitamin tertinggi diikuti oleh beras perang yang dikisar pada 4, 6 dan 8% DP. Ini menunjukkan beras perang dan beras separa kisar mempunyai nilai pemakanan yang lebih daripada beras kisar. Beras kisar (8% DP) mempunyai nilai tertinggi bagi nisbah pemanjangan, nisbah pengembangan, nisbah penyerapan air dan kehilangan pepejal. Beras perang mengambil masa (28 minit) yang lebih lama untuk masak dan nilai ini ketara berbeza dengan masa memasak beras separa kisar dan beras perang.