Microstructure, Water Migration and Texture of Thai Chalky Rice Varieties

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Summary Chalk is an inferior characteristic of rice because it leads to the poor milling quality. In addition, chalky rice is generally considered to have poor cooking and eating qualities. However, the data on the poor cooking and eating qualities of chalky rice is limited, especially in high amylose Thai chalky rice varieties. Therefore, this work aimed to compare the microstructure, water migration during cooking, texture and sensorial qualities of four Thai chalky rice varieties, Prachin Buri2 (PB2), Khao Bahn Nah432 (KBN432), Ayutthaya1 (AY1), and Plai Ngahm Prachin Buri (PNPB), with the translucent Thai rice variety, Phitsanuplok2 (PSL2). The loosely packed cell structure in all chalky rice varieties was observed under scanning electron microscope. KBN432 had the highest degree of chalkiness. Water migrated in the KBN432 with the fastest speed. All cooked chalky rice had lower hardness than the translucent rice, except AY1. Softness scores of chalky rice samples were higher than translucent rice. However, there was no difference in overall acceptability between chalky rice and translucent rice. Therefore, chalky rice varieties studied in this work may be used for consumption with the same quality to the translucent rice variety.

Key Words rice, chalky rice, Thai rice, microstructure, water migration, texture

Materials and Methods

Materials
Five Thai rice varieties, namely Phitsanuplok2 (PSL2), Prachin Buri2 (PB2), Khao Bahn Nah432 (KBN432), Ayutthaya1 (AY1), and Plai Ngahm Prachin Buri (PNPB), were purchased from Thai rice department. Prachin Buri2 (PB2), Khao Bahn Nah432 (KBN432), Ayutthaya1 (AY1), and Plai Ngahm Prachin Buri (PNPB) were chalky rice, while Phitsanuplok2 (PSL2) was translucent rice. Rice grains were dehusked and milled to obtain white rice at the same degree of polishing using the milling machine (model NW1000Turbo, Natrawee Technology Co. Ltd., Chachoengsao, Thailand). Fat and protein of all rice samples analyzed using method of AOAC (6) were 0.19–0.41 g/100 g and 7.62–10.16 g/100 g, respectively. The amylose content of all rice samples analyzed using method of Juliano (7) were 30.99–38.56 g/100 g, which were classified as high amylose rice.

Scanning Electron microscopy (SEM)
All rice grain samples were fractured at the middle of grain and mounted on the stub. Cross-sectioned surface of rice samples were observed under a scanning electron microscope (INSPECT S50, FEI, Netherlands) at an accelerating voltage of 10 kV in high vacuum mode with 100x magnification.

Water uptake
Rice grain samples were boiled in test tube containing with deionized water at 100°C for 60 min. One rice grain was removed from test tube every 5 min, quenched in room temperature water for 1 min, and then blotted.

Rice is one of the main staple grains in the world, especially for the Asian people. The demand on number of rice has increased due to the growth of world population. According to the climate change, some rice varieties have been developed to be resistant to the severe environment in some regions, e.g. flood or drought.

Unfortunately, some of those developed varieties have lots of chalk in their grain. Chalk is the opaque area in the rice grain, which becomes the defect on the appearance. One of the most explanations on the cause of chalk is the high temperature during the grain development stage (1). The chalky part leads to the poor milling quality (2) because rice grains are easily broken at the opaque area during milling, resulting in low head rice yield. Besides, chalky rice is generally considered to have poorer eating qualities (3, 4), so the price of chalky rice is cheap. The cooking quality of chalky rice was also different from the translucent rice (5, 2). However, the data on the cooking and eating qualities of chalky rice is limited, especially in Thai chalky rice varieties. Moreover, most of researches focused on the chalk in low or medium amylose rice varieties, but there is less report on high amylose varieties.

Therefore, this work aimed to compare the microstructure, water migration during cooking, texture and sensorial qualities of four Thai high amylose chalky rice varieties with the translucent Thai high amylose rice variety.

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its surface with cooking paper. The moisture content of the rice grain was measured by hot air oven at 100˚C for 24 h.

Water migration inside rice grain during cooking

Rice grain samples were boiled in 0.1% methylene blue at 100˚C for 20 min. Several rice grains were taken every 5 min and blotted their surface. The rice grain samples were dried in hot air oven at 40˚C for 1 h. The rice grain was polished with a sand paper until reaching to its center. The polished rice grain was attached on the slide glass with glue. The surface of the polished rice was observed under stereomicroscope (model S8APO, Leica, Singapore).

Textural properties of cooked rice

Cooked rice was prepared according to Rachtanapun et al. (8). Two hundred grams of raw rice was rinsed twice with tap water. Then, tap water was added into the washed rice to obtain a weight ratio at 1.8:1 (water: rice). The rice was cooked in a rice cooker (SR-G10; Panasonic Home Appliances Co., Chachoengsao, Thailand) for approximately 20 min.

Texture Profile Analysis (TPA) was used to measure the texture of cooked rice. Before textural measurement, 20 g of cooked rice sample with temperature at 40˚C was packed in a beaker with a diameter of 4 cm with the height of each sample being 2.8 cm. The texture of the cooked rice was measured using a TA.XT plus texture analyser (Stable Micro System, Surrey, UK). Each sample was compressed twice at a test speed 1 mm/s with a cylinder probe (SMS P/36 R) at 45% strain. Hardness and adhesiveness were analyzed from the measured profile. At least 15 samples were measured for each treatment. Each measurement was taken in triplicate.

Sensory Evaluation

The hedonic test was used for sensorial evaluation of cooked rice from all varieties. Ten grams of cooked rice of each variety was served to 50 untrained panelists. The panelists were asked to indicate their liking on overall acceptability, whiteness, softness, stickiness and flavor of cooked rice using a 9-point hedonic scale (1 = dislike very much, 9 = like very much).

Statistical analysis

All experiments were conducted in triplicate. Mean values were compared using analysis of variance (ANOVA). Significant differences among samples were inferred using Duncan’s multiple range test ($p \leq 0.05$) in a software package (SPSS ver. 12.0; SPSS Inc., Chicago, IL, USA).

Results and Discussion

Morphology of rice grain

Figure 1 shows the morphology of all rice varieties used in this work. PSL variety had clear and translucent appearance, while there was opaque area in other rice varieties. Among chalky rice varieties, KBN432 had the highest degree of chalkiness, following by AY1, PJ2 and PY, respectively.

SEM

There was clear difference on the microstructure observed by SEM between translucent and chalky rice (Fig. 2). Scanning Electron Micrographs revealed the dense tightly packed structure inside the PSL2 rice grain, while the disorganized cellular structure was found inside all chalky rice grain at the opaque area. This loosely packed cell structure originated from the center toward the surface of rice grain. This result was consistent well with the several works on the structure of chalky rice ($1$, $2$, $4$).

Water uptake

There was no difference in the water uptake of all rice
varieties for the first 10 min (Fig. 2). After that, the difference in water content among varieties was observed. Water content of all samples kept increasing after fully gelatinized (20 min). Water content of all chalky rice varieties was higher than translucent variety except for AY1. This agrees with the high water absorption of chalky short grain rice than translucent rice reported by Kim et al. (3).

Water migration during cooking

In order to monitor water migration inside rice grain, rice grains from all varieties were boiled in methylene blue solution. Water migration distance was considered from the blue color of methylene blue inside the rice grain (Fig. 4). Even though there was no difference in water uptake among varieties during first 10 min of boiling (Fig. 3), the difference in water migration speeds among samples was found (Fig. 4). KBN432 had dark blue color all over its grain at 10 min of boiling, while the white center area was clearly observed in other samples. This means water migrated inside the KBN432 variety with the fastest speed. This may relate to the highest degree of chalkiness of KBN432. The loosely packed structure at the opaque part of the KBN432 may be the channel for water to enter into the grain. This agrees well with the report on the shorter cooking time of chalky rice than translucent rice (2). The authors explained that the fast diffusion of water was attributed to the air space and disorganized cellular structure of chalky rice. However, even though AY1 had the high degree of chalkiness following KBN432, water migration speed inside AY1 became the lowest. This is consistent well with the low speed of water uptake of AY1 (Fig. 3). The slow water migration in AY1 may be attributed to its highest pasting temperature, measured by rapid visco-analyzer (RVA) (data not shown), and its highest protein content among samples (10.16 g/100 g). The high protein content may restrict the swelling of starch granules, resulting in slow water migration (9). Therefore, it is not only the degree of chalkiness, but also composition and gelatinization property which may have an influence on the water migration speed inside the rice grain.

Textural properties of cooked rice

All cooked chalky rice varieties had lower hardness than the translucent rice variety (PSL2), except AY1 (Fig. 5). The softer texture may be attributed to the loosely packed structure of chalky rice (Fig. 2). This is consistent with the report on texture of low amylose chalky rice (2). The low amylose content chalky rice was softer than the translucent rice due to the lower

<table>
<thead>
<tr>
<th>Rice varieties</th>
<th>Overall acceptabilitya</th>
<th>Whitenessa</th>
<th>Softness</th>
<th>Stickinessa</th>
<th>Flavora</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSL2</td>
<td>5.14±1.67</td>
<td>6.42±1.54</td>
<td>4.04±1.64c</td>
<td>4.80±1.55</td>
<td>4.92±1.67</td>
</tr>
<tr>
<td>PNPB</td>
<td>5.70±1.43</td>
<td>5.82±1.69</td>
<td>5.68±1.82a</td>
<td>5.46±1.59</td>
<td>5.20±1.54</td>
</tr>
<tr>
<td>PB2</td>
<td>5.64±1.75</td>
<td>6.46±1.59</td>
<td>4.46±1.99ab</td>
<td>4.84±1.65</td>
<td>5.16±1.58</td>
</tr>
<tr>
<td>AY1</td>
<td>5.58±1.54</td>
<td>6.50±1.64</td>
<td>4.62±1.74ab</td>
<td>4.88±1.71</td>
<td>5.18±1.41</td>
</tr>
<tr>
<td>KBN432</td>
<td>5.44±1.73</td>
<td>6.06±1.80</td>
<td>4.84±1.99b</td>
<td>5.20±1.52</td>
<td>4.86±1.82</td>
</tr>
</tbody>
</table>

a,b,c Means in the same column followed by different letters are significantly different (p≤0.05). a No significant difference between means in the same column (p>0.05).
Amylose content and disordered structure of chalky rice. The high hardness of AY1 may correlate to its low moisture content after cooking as shown in the lowest moisture content among samples at 20 min of boiling (Fig. 3). There was no difference in the adhesiveness between the translucent and chalky rice varieties, except for AY1.

Sensory evaluation

Since all rice varieties used in this work were high amylose rice, they had hard texture and less stickiness. Normally, Thai consumers prefer rice with the soft texture. Therefore, the score from hedonic test in all attributes were low (less than 6) (Table 1). However, the softness scores of chalky rice samples were higher than translucent rice. This may be because chalky rice samples had lower hardness than translucent rice (Fig. 5). There was no difference in score of stickiness, flavor, whiteness and overall acceptability between chalky rice and non-chalky rice (p > 0.05). Therefore, it can be said that there was no difference in eating quality between chalky rice and translucent rice varieties used in this work.

Conclusion

The difference in microstructure between chalky rice and translucent rice varieties were shown in this work. The fast water migration and the soft texture of chalky rice may be attributed to the loosely packed structure. However, there was no difference in overall acceptability between chalky rice and translucent rice. Therefore, chalky rice varieties studied in this work may be used for consumption with the same quality to the translucent rice variety.

Disclosure of State of COI

No conflicts of interest to be declared.

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REFERENCES