Packaging techniques to prolong the shelf life of brown rice and partially milled rice at ambient storage
(Teknik pembungkusan untuk memanjangkan jangka hayat beras perang dan beras separa proses dalam penyimpanan ambien)

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Key words: brown rice, partially milled rice, packaging techniques, storage, physical quality

Abstrak
Padi varieti Q 34 dikilang dengan menggunakan pengisar padi perintis MARDI berkeupayaan 2 t/jam untuk mendapatkan beras perang dan beras separa kisar (2–3% darjah pengilangan). Beras dibungkus menggunakan teknik pembungkusan hampagas, penyerapan oksigen, pembungkusan bergas karbon dioksida, pembungkusan beg plastik polietilena (PE) sebagai kawalan dan disimpan selama 6 bulan pada suhu bilik.

Beras perang dapat disimpan selama 6 bulan manakala beras separa kisar selama 4 bulan. Tiada serangan serangga berlaku dalam kaedah pembungkusan yang telah digunakan. Bagaimanapun terdapat serangan serangga dalam pembungkusan plastik PE selepas 3 bulan penyimpanan. Berbanding dengan pembungkusan PE (kawalan), teknik pembungkusan yang digunakan untuk beras perang menunjukkan kandungan lembapan yang rendah, ketumpatan pukal yang tinggi, biji rosak dan biji retak yang stabil dan tiada perbezaan pada tekstur dan nilai rasa nasi. Bagaimanapun, kandungan asid lemak bebas dalam pembungkusan kawalan (PE) adalah lebih rendah daripada teknik pembungkusan yang lain. Teknik pembungkusan untuk beras separa kisar tidak memberi banyak kebaikan dalam pengekalan mutu ketika penyimpanan.

Abstract
Paddy Q 34 was milled using the MARDI pilot rice mill with a capacity of 2 t/h to produce brown rice and partially milled rice (2–3% milling degree). Rice samples were packed by the packaging techniques of vacuum, oxygen absorbent, carbon dioxide gas, polyethylene plastic (PE) as control and stored at ambient temperature for 6 months.

Brown rice and partially milled rice can be stored for 6 months and 4 months respectively without insect infestation. Insect infested brown rice sample was found in PE packaging (control) at 3 months of storage. All the packaging techniques used were lower in moisture content, higher in bulk density, lower and stable in damaged grain and cracked grain respectively and not significantly different in texture and flavour of cooked rice compared to the PE packaging. Generally, the levels of free fatty acids in control packaging (PE) were much lower.

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lower compared to the other techniques. The packaging techniques used had not much beneficial effect on the quality maintenance for partially milled rice during storage.

**Introduction**

Brown rice, also known as cargo rice or loonzain, is rice with husks removed. It consists of pericarp, seed coat, testa, aleurone layer, germ or embryo and endosperm. Its nutritional quality is higher than milled rice (Ajimilah and Rosniyana 1994; Rosniyana et al. 1997; Ory et al. 1980) particularly with respect to the fat, protein, crude fibre, minerals (phosphorus, potassium, sodium, calcium and iron) and vitamins (thiamine, niacin, and riboflavin).

Brown rice has the advantage of having three times more fibre than white rice. It has probably a bigger health benefit than the fortified vitamins (Sue Gilbert 2000). In addition to being health food, brown rice has been reported to prevent a number of diseases e.g. diabetes and disorders related to the kidney, blood and heart. Though the consumption of brown rice is relatively new in Malaysia, it is easily available in the local shops and supermarkets in normal and vacuum packagings.

Brown rice is expected to store for only 6 months under average condition. This is because of the presence of essential fatty acid which quickly go rancid as they oxidize (Anon. 2002). Storing brown rice offers considerable advantages i.e. handling a smaller quantity and the requirement of less space, as the husk contributes about one-fourth of the weight and over one-third the volume of paddy (Houston 1972).

Brown rice is more nutritious than milled rice but there is a traditional consumer preference for white (milled) rice which has better appearance, is translucent and more palatable. The short shelf life has been implicated as a deterrent to the amounts of brown rice packaged for direct consumption (Schutz and Fridgen 1974).

A survey conducted in Kedah (northern state of Peninsular Malaysia) indicated that about 34.2% of the respondents (total number of 315) consumed brown rice. Most of them were Chinese, followed by Indian and Malay (Ibni et al. 2000). Brown rice can be cooked as fried rice, ‘nasi lemak’, tomato rice, porridge and used in several local cakes. An alternative to brown rice is partially milled rice with 2–3% degree of milling to give it a slight ‘nutty’ taste.

The limited consumption of brown rice is due to the accumulation of free fatty acid in rice stored under warm and humid conditions. Ibni et al. (1997) reported that free fatty acid content is between 8.3% and 15.3%, and after 6 months the content is between 53.0% and 65.3%. Fatty acids can be released by lipase present in the rice aleurone (bran) layer of damaged grains and by high lipase-containing bacteria and fungi adhering to rice (DeLucca et al. 1978). Both lipolytic bacteria and fungi are present in sufficient numbers to cause rancidity and off-flavour in stored brown rice, causing its quality to deteriorate during storage mainly because of oxidative changes (Sowbhagya and Bhattacharya 1976) and lipolytic hydrolysis of about 3% oil present in it (Hunter et al. 1951).

The main objective of this study was to prolong the shelf life of semi-processed rice by applying various packaging techniques to improve the keeping quality.

**Materials and methods**

**Brown rice and partially milled rice**

A high quality paddy, Q 34 (Plate 1), was milled using the MARDI pilot rice mill with 2 t/h capacity to produce brown rice (Plate 2) and partially milled rice, 2–3% milling degree (Plate 3). The indented rice grader was used to obtain the head rice of brown rice and partially milled rice. Samples were fumigated in a closed container for 7 days by using phostoxin
Plate 1. Paddy Q 34
Plate 2. Brown rice
Plate 3. Partially milled rice
Plate 4. Oxygen absorber (1) and vacuum packaging (2)
Plate 5. Vacuum packaging machine
Plate 6. CO₂ gas flushing unit
Plate 7. Gas detector meter
Plate 8. Oxygen absorber (Z 100 Ageless)
Packaging of brown rice and partially milled rice

(1–3 tablets per tonne rice). After fumigation, the container was left open for 3–4 days for air aeration before the rice is packed. A total of 252 kg of brown rice and partially milled rice samples were packed in bags of 3 kg each.

Packaging techniques
Four packaging techniques for storage were used:

1. heat-sealed polyethylene bag, PE (control samples); water vapour transmission rate = 22 g/m². 24 h, 40 °C, 90% RH; oxygen permeability = 2900 cm³/m². 24 h.atm., carbon dioxide permeability = 9100 cm³/m². 24 h.atm.

2. heat-sealed laminated bag of oriented polypropylene/polypropylene, OPP/PP (vacuum samples, PPV); water vapour transmission rate = 3–5 g/m². 24 h, 40 °C, 90% RH.; oxygen permeability = 2500 cm³/m². 24 h.atm.; carbon dioxide permeability = 8500 cm³/m². 24 h.atm.

3. heat-sealed laminated bag of oriented polypropylene/polypropylene, OPP/PP (oxygen absorber samples, PPO)

4. heat-sealed laminated bag of polyester/polyethylene/low linear density polyethylene, PET/PE/LLDPE (gas samples, CO₂); water vapour transmission rate = 20 –24 g/m². 24 h, 40 °C, 90% RH; oxygen permeability = 95 cm³/m². 24 h.atm.; carbon dioxide permeability = 240 cm³/m². 24 h.atm. The CO₂ gas was flushed at 75 –80% vacuum, 20% pre-setting gas with a flow rate of 35 –40 litres per minute.

Each treatment had 12 bags kept for 6 months storage period at ambient condition.

Quality analysis
Samples were drawn at one-month intervals, and determined for moisture content, bulk density, head rice, damaged grain, cracked grain, free fatty acid (FFA) and beaker test (for texture and flavour). Moisture was determined by the Kett Moisture Meter. Bulk density was measured by a Hectolitre-weight (kg/hl). The head rice was obtained by 2 min rotating time of an indented cylinder grader of 4.75 with a catch trough plate at 0 degree. Damaged grain was determined by the hand picking method from 50 g of head rice sample. Cracked grain was determined by selecting 300 whole grains and placing them in a perforated tray (100 grains each tray). Using the cracked grain detector, a light was passed through the rice kernels and with a magnifying glass, crack lines can be observed and counted. The measurement of FFA has been recommended as a criterion for deterioration of the grain (Zeleny and Coleman 1938; and Yasumatsu and Moritaka 1964; Barber 1972). FFA was determined using AOAC standard methods. The data obtained were statistically analysed.

Beaker test
A stored sample of 9 g weight and 20.7 mL water were placed in a glass beaker and covered with aluminium foil. The rice was cooked in an electrical rice cooker and kept warm for 30 min. Texture and flavour were measured subjectively by 6–8 panellists. Panellists had to compare the stored cooked rice with fresh cooked rice, and give a score of 1–4 (moderately like compared to the fresh sample), 5 (like as much as the fresh sample) or 6–10 (like more than the fresh sample).

Results and discussion
Packaging techniques in brown rice
No insect infestation was observed in all the packaging techniques over the 6 months of storage. Insect infestation only occurred in the control (PE packaging) from the beginning of 3 months storage (Table 1).
Table 1. The quality parameters of brown rice after 6 months of storage with four packaging techniques (Dec. 1996)

<table>
<thead>
<tr>
<th></th>
<th>PE</th>
<th>PPO</th>
<th>PPV</th>
<th>CO₂ §</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (% wb)</td>
<td>15.0a(0.2)</td>
<td>14.5(0.3)</td>
<td>14.5b(0.2)</td>
<td>13.7c(0.4)</td>
</tr>
<tr>
<td>Bulk density (kg/hl)</td>
<td>70.9b(1.1)</td>
<td>71.8(0.4)</td>
<td>71.9b(0.5)</td>
<td>73.6a(0.6)</td>
</tr>
<tr>
<td>Head rice (%)</td>
<td>98.0a(0.2)</td>
<td>98.0(0.2)</td>
<td>97.8a(0.3)</td>
<td>97.8a(0.4)</td>
</tr>
<tr>
<td>Damaged grain (%)</td>
<td>9.4a(1.5)</td>
<td>9.4(1.4)</td>
<td>9.3a(2.0)</td>
<td>2.3b(0.5)</td>
</tr>
<tr>
<td>Cracked grain (%)</td>
<td>6.1a(1.6)</td>
<td>5.3(1.3)</td>
<td>5.0a(1.3)</td>
<td>0.9b(0.5)</td>
</tr>
<tr>
<td>Free fatty acid (%)</td>
<td>12.1b(1.4)</td>
<td>15.6(1.7)</td>
<td>16.2a(1.1)</td>
<td>11.8c(0.9)</td>
</tr>
<tr>
<td>Beaker test: Texture</td>
<td>4.5a(0.4)</td>
<td>4.4(0.3)</td>
<td>4.5a(0.3)</td>
<td>4.3a(0.2)</td>
</tr>
<tr>
<td>Flavour</td>
<td>4.6a(0.2)</td>
<td>4.6(0.3)</td>
<td>4.6a(0.3)</td>
<td>4.6a(0.2)</td>
</tr>
<tr>
<td>Whiteness number</td>
<td>nm</td>
<td>nm</td>
<td>nm</td>
<td>nm</td>
</tr>
<tr>
<td>Insect</td>
<td>975(61)*</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
</tr>
</tbody>
</table>

*Carried out in February 2000
Average (SD)
nm = not monitored
*Number of living insects after 6 months of storage (3 months)

Mean values within the same row with the same letter are not significantly different at $p = 0.05$

The moisture content increased in all the packaging techniques throughout the 6 months of storage (Figure 1) with significantly higher levels in PE packaging at $p = 0.05$ (Table 1). The moisture content was more stable in CO₂ packaging (Figure 1). Ory et al. (1980) reported that the CO₂ packaging gives better protection against moisture changes during storage. The concentration of CO₂ gas inside the bags was determined to range from 38–44%. CO₂ concentration above 35% must be maintained for at least 10–44 days for successful insect control (Anis and van S. Greve 1984). Rice in PE packaging had a lower bulk density but was not significantly different ($p = 0.05$) from PPO and PPV packagings (Table 1). The bulk density in CO₂ packaging was most stable (Figure 1) and significantly different ($p = 0.05$) compared to PE packaging.

The head rice contents for all the packaging techniques were almost similar (Figure 1) and were not significantly different (Table 1). The presence of insects in PE packaging probably affected the bulk density but not the head rice of brown rice. The presence of both damaged and cracked grain in PE packaging was slightly higher (Table 1) but was not significantly different from PPO and PPV packagings (Table 1). With an increase in insect activity, there is an increase in kernel damage (Indudhara Swamy et al. 1993). The lowest content of both damaged and cracked grain was in CO₂ packaging, most probably due to the good quality of its initial sample and being most stable throughout the storage (Figure 2).

The FFA in all packagings increased, with higher levels in both PPO and PPV packagings which showed a significant difference at $p = 0.05$ compared to PE packaging (Figure 2). Sharp and Timme (1986) reported that FFA levels for polyethylene bag samples are lower than for vacuum samples. There was a steady increase in FFA in CO₂ packaging throughout the storage but was not significantly different at $p = 0.05$ from PE packaging. Ory et al. (1980) indicated that at ambient storage there is no consistent significant decrease in FFA in laminated bags plus CO₂.

Packaging techniques in partially milled rice

The partially milled rice was stored and lasted only 4 months due to heavy insect infestation in all the packaging techniques with PE packaging being the worst. The
Figure 1. Moisture content, bulk density and head rice in brown rice and partially milled rice during 6 months and 4 months of storage respectively.
Figure 2. Damaged grain, cracked grain and free fatty acid in brown rice and partially milled rice during 6 months and 4 months of storage respectively.
Packaging of brown rice and partially milled rice

The quality parameters of partially milled rice during 4 months of storage with three packaging techniques (May 1997)

<table>
<thead>
<tr>
<th></th>
<th>PE</th>
<th>PPO</th>
<th>PPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (% wb)</td>
<td>14.6a(0.5)</td>
<td>14.6a(0.9)</td>
<td>14.4a(0.1)</td>
</tr>
<tr>
<td>Bulk density (kg/hl)</td>
<td>73.5a(0.6)</td>
<td>73.7a(0.4)</td>
<td>73.5a(0.4)</td>
</tr>
<tr>
<td>Head rice (%)</td>
<td>94.9b(0.7)</td>
<td>94.9b(0.3)</td>
<td>95.8a(0.8)</td>
</tr>
<tr>
<td>Damaged grain (%)</td>
<td>5.2a(0.3)</td>
<td>5.5a(0.7)</td>
<td>5.4a(0.8)</td>
</tr>
<tr>
<td>Cracked grain (%)</td>
<td>0.8a(0.5)</td>
<td>0.6a(0.4)</td>
<td>1.0a(0.8)</td>
</tr>
<tr>
<td>Free fatty acid (%)</td>
<td>57.8a(6.8)</td>
<td>63.7a(7.7)</td>
<td>64.2a(7.0)</td>
</tr>
<tr>
<td>Beaker test: Texture</td>
<td>4.8a(0.5)</td>
<td>4.8a(0.5)</td>
<td>4.8a(0.5)</td>
</tr>
<tr>
<td>Flavour</td>
<td>4.9a(0.1)</td>
<td>4.9a(0.1)</td>
<td>4.9a(0.1)</td>
</tr>
<tr>
<td>Whiteness number</td>
<td>31.9a(0.8)</td>
<td>31.7a(0.6)</td>
<td>31.8a(0.6)</td>
</tr>
<tr>
<td>Insects</td>
<td>Uncountable¹</td>
<td>Uncountable²</td>
<td>Uncountable²</td>
</tr>
</tbody>
</table>

Average (SD)
¹At 4 months of storage
²After 4 months of storage
Mean values within the same row with the same letter are not significantly different at \( p = 0.05 \)

moisture content gradually increased (Figure 1) in all packaging techniques with no significant difference at \( p = 0.05 \) (Table 2). The head rice content was slightly higher in PPV packaging (95.8 ± 0.8%), and had a significant difference at \( p = 0.05 \) compared to PE packaging (94.9 ± 0.7%). Parameters such as bulk density, damaged grain and cracked grain were not significantly different \( (p >0.05) \) in all the packaging techniques (Table 2).

The FFA levels steadily increased throughout the storage period (Figure 2) and their values did not show much variation among the packaging techniques (no significant difference at \( p = 0.05 \)). This was probably because the loose bran on rice kernel surface was exposed to the lipolytic enzymes resulting in faster activity. Thus, its value increased several folds as compared to the brown rice samples (Table 2). The whiteness of the rice was not significantly different (Table 2 and Figure 3).

Beaker test
There was no significant difference \( (p = 0.05) \) in both flavour and texture detected in rice from all the packaging techniques used for brown rice and partially milled rice. Both texture and flavour of the stored cooked rice were close to those of fresh cooked rice (Brown rice: 4.3–4.6; partially milled rice: 4.8–4.9). Ory et al. (1980) reported that no rancid or off-odour developed in brown rice stored for 7 months at ambient condition in plastic and laminated films, with and without carbon dioxide.

Conclusion
The simplest packaging technique is the polyethylene bag. Using this technique, brown rice and partially milled rice can be stored at ambient condition for only 3 months due to subsequent insect infestation.
However, infested brown rice did not show inferior quality in terms of head rice, bulk density, damaged grain, cracked grain, and also in texture and flavour of cooked rice. The improved packaging techniques of vacuum, oxygen absorbent and CO₂ gas could be applied effectively for disinestation of brown rice, which can then store longer. However there was not much advantage using these techniques for partially milled rice storage. An unattractive appearance accompanied by heavily infestation indicated that partially milled rice cannot be stored for more than 4 months. The laminated films of PET/PE/LLDPE plus CO₂ gas obviously resulted in quality parameters being most stable and consistent throughout the storage period.

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