Physical and milling quality of solar regenerated desiccant dried paddy
(Mutu fizikal dan pengilangan padi menggunakan bahan pengering jana semula suria)

S. Wahid* and M. Ahmad Hajazi**

Key words: physical quality, milling quality, solar regenerated desiccant drying, paddy

Abstract
Two drying methods of slow drying process for partially dried paddy were studied. Firstly, solar regenerated desiccant drying at a temperature of 27.0 ± 0.5 °C and relative humidity of 63.8 ± 5.3%. Secondly, air heated drying at a temperature of 31.0 ± 2.8 °C and relative humidity of 66.0 ± 10.2%. Partially dried paddy at moisture content of 18.1% and 20.2% were used in the first and second experiments respectively. The drying period was 13 days (130 h) and 10 days (120 h) respectively. Physical and milling qualities were analysed. Apparently only cracked grain and rice whiteness were significantly different at \( p = 0.01 \). The cracked grain is lower and rice whiteness is higher through the solar regenerated desiccant drying compared to air heated drying.

Introduction
Mechanical drying is widely used in Malaysia. It is more applicable, easily controlled and produces paddy with higher quality. Batch-type drying is more popular than continuous flow drying due to its lower capital cost and minimum maintenance. A total of 1.62 million tonnes of paddy was produced from 387 000 hectares of paddy growing area in Peninsular Malaysia (Supaad and Ali 1994). The capacity of the existing driers was 1.81 million tonnes/year (Omar, Y., Status of commercially milled rice in Malaysia, BERNAS, Alor Setar, Kedah, pers. comm. 1990). Hence, the delay in drying is not to be a major problem in paddy and rice processing industry.

Newly harvested paddy should be kept at 18% moisture content (partially dried) (Anon. 1985). Paddy will be partially dried with the use of pre-drying plant to a level where temporary storage is possible without adversely affecting grain quality (Anon. 1990). Higher moisture grain can be dried in a controlled condition in storage (not field dried) to reduce milling losses (Darby 1987).

Achieving the recommended level of moisture content is required to avoid deterioration and increase the overall drying output of the complex. The most recognized harmful effects are discolouration, loss in viability, heating and mustiness, biochemical changes, loss in weight and possibly production of toxins (Girish and Goyal 1986).

Most farmers and millers in Malaysia are neglecting the old method of sun drying. Now mechanical driers are more beneficial, but unfortunately a bottleneck still occurs especially during the wet season. To overcome this problem, two-stage drying is normally practised. First stage is fast drying to reduce the initial moisture content of wet
Solar regenerated desiccant dried paddy

paddy to 18 – 20% (partially dried). Paddy is then transferred to another holding bin for second stage drying (slow drying). Low temperature drying is a process which utilizes either natural air or air heated by only a few degrees above ambient temperature for drying, depending upon the ambient relative humidity. It is a slow process which takes around 7–15 days depending on the weather conditions (Aldas et al. 1995).

If the ambient relative humidity more than 75%, air heated drying must be used (Bakker-Arkema and Salleh 1985). The in-store drying should be operated with the relative humidity of its inlet air within the range of 65 – 75% (Tumambing et al. 1995). Solar energy has potential application to low temperature in-store drying. Conditions in tropical and sub-tropical countries make the use of solar energy highly recommendable for drying (Gary and Kumar 2001). Solar energy is widely available in Malaysia with an average of 7 h daily ranging from 400 – 800 W/m² or 9 600 – 19 200 Wh/m² (Othman et al. 2001).

The main purpose of this study was to evaluate the physical and milling qualities of solar regenerated desiccant dried paddy and compare to the air heated low temperature drying.

Materials and methods

Solar regenerated desiccant drying (SRDD)
The solar regenerated desiccant unit (Figure 1) with measurement of 3.0 m length, 2.3 m width and 0.5 – 1.0 m height consisted of a backward-curved centrifugal fan, an air inlet tube, air outlet tube, three compartments of silica gel and a black painted surface (Plate 1) (Wahid et al. 1999).

In the daytime (heating operation) the unit was operated and exposed to the sunshine for 8 h (1000 h to 1800 h) to dry silica gel (3 compartments @ 8 kg each). A Pyranometer (Solar Integrator CC12, KIPP & ZONEN) was used for measuring light intensity. At night, the unit (drying and cooling operation) was operated for 10 h (2100 h to 0700 h), where the solar regenerated desiccant unit was connected to a cylindrical metal bin dryer (Figure 2) which contained 3.6 ts (at a 3.6 m grain depth) of partially dried paddy at 18.1 ± 0.3% moisture content.

A data logger (accuracy: ± 0.15%) was installed to record measurements (interval of one hour) of both ambient and drying air temperatures. Temperature was measured with a T-type thermocouple and relative humidity was determined using dry and wet-bulb thermometer.

Air heated low temperature drying (AHLTD)
A cylindrical metal bin dryer (Plate 2) with measurement of 3.6 m height and 1.5 m diameter containing partially dried paddy (2.5 t) at 20.2 ± 1.2% moisture content, was fitted with a perforated screen floor about 0.8 m high from the concrete base. The system was operated for 12 h continuously (0800 h to 2000 h). The ambient air was heated using an electrical heater, with a cut-off temperature of 35 °C (Wahid et al. 1995).

The backward curve centrifugal fan driven by a 2 hp electric motor conveyed the hot air to the batch of paddy grain. Both ambient and air-drying temperatures were recorded with data logger. Temperature was measured with a T-type thermocouple and relative humidity was determined using dry and wet-bulb thermometer.

Physical quality
Final samples were taken from different levels (top, middle and bottom), mixed and portioned using sample divider such that the samples would represent the whole drying experiment for analysis, viz. cracked grain, bulk density and a germination test. The cracked grain was determined by selecting 300 paddy grains, put into perforated plastic trays (100 grains per tray). The tray was placed into a cracked grain detector and moved up and down to allow the light to shine through the grain. Using a magnifying
Figure 1. Solar regenerated desiccant unit

1. Fan
2. Rubber tube
3. Air inlet tube
4. Silica gel
5. Heat exchanger
6. Air outlet tube

Plate 1. Solar regenerated desiccant unit
Solar regenerated desiccant dried paddy

glass, crack lines can be observed and counted.

Hectoliter-weight instruments were used to determine the bulk density. Germination tests were carried out at room temperature by growing 100 paddy grains in a petri dish, which contained moistened tissue paper. Samples were examined at intervals of 5 days. Paddy kernels with both roots and shoots were considered germinated.

**Milling quality**

A 135 g sample of paddy grains was dehulled by a rubber roll huller (Satake brand) and produced brown rice, then polished for one minute by a Satake polisher. A 100 g sample of milled rice was further processed for head rice and broken rice through a Satake indented cylindrical grader, no. 4.75, for 2 min. The percentage of total milled rice was calculated based on the weight of 135 g of paddy whereas the percentage of head rice recovery was based on the weight of 100 g of milled rice.

*Figure 2. Solar regenerated desiccant unit (A) and cylindrical metal bin dryer (B) in operation with partially dried paddy*
Results and discussion

Solar regenerated desiccant drying (SRDD)
A unit of solar regenerated desiccant required 8 h in the daytime to dry silica gel from 23% to 9% moisture content. The highest intensity of solar radiation was recorded as 947 Wh/m² between 1300 h and 1400 h and its average was 604.8 Wh/m². The 3.6 t of partially dried paddy with an initial moisture content of 18.1 ± 0.3% required 13 days to dry to 13.7 ± 0.9% moisture content (Table 1). During the cooling operation (night time) the drying temperature and the relative humidity were 27.0 ± 0.5 °C and 63.8 ± 5.3%, respectively. The ambient temperature and relative humidity during the operation were 23.5 ± 0.6 °C and 85.0 ± 3.2%, respectively. In general, an equilibrium relative humidity less than 70% is required to avoid mould contamination of paddy (Boxall and Calverly 1985).

Air heated low temperature drying (AHLTD)
The ambient temperature was heated from 27.4 ± 3.5 °C to 31.0 ± 2.8 °C and the relative humidity reduced from 77.3 ± 12.3% to 66.0 ± 10.2% (Table 1). The drying process required 10 days to reach a final moisture content of 14.2 ± 0.1% from the initial moisture content of 20.2 ± 1.2%. Apparently, the results showed that the air heated low temperature drying had a higher drying rate compared to the solar regenerated desiccant drying and could be observed by its equation given (Figure 3). With that, the moisture could be removed faster at 0.67% per day (for AHLTD) as compared to 0.36% per day (for SRDD).

Table 1. Drying parameters of solar drying and cooling system and air heated low temperature drying system in slow drying process

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Solar regenerated desiccant drying¹</th>
<th>Air heated low temperature drying²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy drying capacity (t)</td>
<td>3.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Initial moisture content (%), wet basis</td>
<td>18.10 ± 0.27</td>
<td>20.24 ± 1.18</td>
</tr>
<tr>
<td>Final moisture content (%), wet basis</td>
<td>13.70 ± 0.86</td>
<td>14.20 ± 0.14</td>
</tr>
<tr>
<td>Ambient air: Temperature (°C)</td>
<td>23.46 ± 0.62</td>
<td>27.39 ± 3.46</td>
</tr>
<tr>
<td>Relative humidity (%), wet basis</td>
<td>85.04 ± 3.22</td>
<td>77.33 ± 12.26</td>
</tr>
<tr>
<td>Drying air: Temperature (°C)</td>
<td>26.99 ± 0.45</td>
<td>30.99 ± 2.83</td>
</tr>
<tr>
<td>Relative humidity (%), wet basis</td>
<td>63.84 ± 5.30</td>
<td>66.00 ± 10.23</td>
</tr>
<tr>
<td>Drying period: days (h)</td>
<td>13 (130)</td>
<td>10 (120)</td>
</tr>
</tbody>
</table>

¹System operated for 10 h (2100 h–0700 h) per day until complete drying
²System operated for 12 h (0800 h–2000 h) per day until complete drying

Figure 3. Drying curve of solar regenerated desiccant drying and air heated low temperature drying
Generally, the moisture content decreases very rapidly while the drying period increases, but then it decreases much less rapidly as the drying period increases further.

**Physical quality**

With the use of air heated drying, percentage of cracked grain was increased by 9%, and for solar regenerated desiccant drying by 6%. This difference was significant at \( p = 0.01 \) (Table 2). The higher number of cracked grain might be affected by heat used. The germination was slightly lower after air heated drying (94.0 ± 2.7%) but not significantly different at \( p = 0.05 \) with solar regenerated desiccant drying (97.9 ± 0.2%). The bulk density was almost the same and not significantly different at \( p = 0.05 \).

**Milling quality**

The increase in cracked grain after air heated drying did not differ significantly in both rice yield and head rice recovery compared to the solar regenerated desiccant drying. The rice yield and head rice recovery were reduced with the ratio decreased to 0.987 and 0.976, respectively (solar regenerated desiccant drying: 0.999 and 0.995, respectively). Milling quality is a great deal dependent upon the inherent properties of the paddy during harvesting and drying, storage conditions and partly on the milling machinery, operating conditions and varieties of paddy (U Myint Pe 1985). The whiteness of rice after the solar regenerated desiccant drying had better translucency and was more consistent than the whiteness of rice by air heated drying, showing a significant different at \( p = 0.01 \) (Table 2).

**Conclusion**

Solar regenerated desiccant drying produced a good physical and milling quality of paddy/rice in terms of lower cracked grain and better rice whiteness. Most of its physical and milling quality were not significantly different compared to the air heated drying. However, its drying period was quite long compared to the air heated drying. A solar regenerated desiccant drying showed a suitable alternative system to air heated slow drying process for paddy, and its drying cost should be much lower because hot air was not required during the operation.

**Acknowledgement**

The authors would like to thank the supporting staff, Mr Elias Zakaria of MARDI Bukit Raya Station for his commitment in conducting this study.

---

**Table 2. Physical and milling quality of paddy by two methods of slow drying process**

<table>
<thead>
<tr>
<th></th>
<th>Solar regenerated desiccant drying(^1)</th>
<th>Air heated low temperature drying(^2)</th>
<th>df</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk density (kg/hl)</td>
<td>51.02 ± 0.55</td>
<td>51.14 ± 1.13</td>
<td>9</td>
<td>0.23 ns</td>
</tr>
<tr>
<td>Cracked grain (%)</td>
<td>8.70 ± 1.24</td>
<td>10.94 ± 0.89</td>
<td>4</td>
<td>3.94**</td>
</tr>
<tr>
<td>Germination (%)</td>
<td>97.89 ± 0.16</td>
<td>94.02 ± 2.72</td>
<td>3</td>
<td>2.46 ns</td>
</tr>
<tr>
<td><strong>Milling</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown rice (%)</td>
<td>79.23 ± 0.13</td>
<td>77.79 ± 1.98</td>
<td>6</td>
<td>1.76 ns</td>
</tr>
<tr>
<td>Rice yield (%)</td>
<td>67.91 ± 0.33</td>
<td>66.08 ± 3.86</td>
<td>6</td>
<td>1.15 ns</td>
</tr>
<tr>
<td>Head rice (%)</td>
<td>84.80 ± 0.90</td>
<td>73.81 ± 11.72</td>
<td>4</td>
<td>1.87 ns</td>
</tr>
<tr>
<td>Whiteness (unit)</td>
<td>46.63 ± 0.49</td>
<td>43.65 ± 1.17</td>
<td>7</td>
<td>4.75**</td>
</tr>
</tbody>
</table>

\(^1\)System operated for 10 h (2100 h–0700 h) per day until complete drying

\(^2\)System operated for 12 h (0800 h–2000 h) per day until complete drying

ns = Not significant at \( p = 0.05 \), **Significant at \( p = 0.01 \)

kg/hl = kilogramme/hectolitre
References

Abstrak
Dua kaedah pengeringan secara perlahan untuk mengering padi separa kering telah dikaji. Pertama, menggunakan bahan pengering jana semula suria pada suhu 27.0 ± 0.5 °C dan kelembapan bandingan udara, 63.8 ± 5.3%. Kedua, menggunakan pengeringan udara panas pada suhu 31.0 ± 2.8 °C dan kelembapan bandingan udara, 66.0 ± 10.2%. Padi dalam keadaan separa kering dengan kandungan lembapan 18.1% digunakan dalam ujian pertama dan 20.2% dalam ujian kedua. Masa pengeringan masing-masing ialah 13 hari (130 jam) dan 10 hari (120 jam). Mutu fizikal dan mutu pengilangan padi mempunyai perbezaan amat bererti pada p = 0.01. Kandungan biji retak dan keputihan beras mempunyai perbezaan amat bererti pada p = 0.01. Masa pengeringan bahan pengeringan jana separa suria lebih rendah dan keputihan berasnya lebih tinggi jika dibandingkan dengan pengeringan udara panas.

Accepted for publication on 25 June 2003