Mix Drying Technique to Conserve the Quality of Asian Rice *

—Low Input Technology for Reducing Postharvest Losses of Staples in Southeast Asia —

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Abstract

In Thailand, to avoid the degradation of fresh paddy after harvesting, we investigated a pre-drying storage treatment consisting of uniform mixing of an absorbent such as dried rice husk, dried paddy, or tapioca pearl with fresh paddy. A mixing, storage, and drying model was developed to calculate the mixture ratio and changes in moisture content (MC). The equilibrium moisture content (EMC) of the mixture of fresh paddy and absorbent (dried paddy or tapioca pearl) was almost equal to the average MC of the weight ratio of the mixture. The weight ratio of the mixture was calculated for an EMC below 17%, which is the maximum moisture content necessary to conserve grain quality for short-term storage. Mixing dried rice husk with fresh paddy is a simple and effective pre-drying method for maintaining rice quality. While tapioca pearl served as an effective absorbent, it is necessary to improve its firmness to ensure its reusability.

[Keywords] drying, mixing, Indica rice, quality, absorbent, post harvest, Asia

I Introduction

In Southeast Asia, the post-harvest loss in cereal is estimated to be 20–30%. Because of the high temperature and humidity in this area, post-harvest losses are thought to be caused by the degradation of grain quality due to insufficient drying after harvesting. However, installing and operating storage and drier systems is costly and therefore not economically viable. Consequently, the development of economical materials and drying and processing techniques are needed.

In Thailand, combines are now used to a large extent to harvest paddy. In fact, more than 40% of paddy is harvested using combines. As a result, the problem of post-harvest deterioration management, especially drying, is increasing. Paddy with high moisture content (MC) is occasionally piled up on the ground after harvesting without treatment, resulting in the deterioration of grain quality. A large quantity of paddy with a high MC that is harvested using combines is brought to rice mills which have dryer facilities; however, the drying capacity and efficiency is comparatively low given the large quantity of paddy. Paddy with a high MC will easily undergo lactic acid fermentation. A critical MC of 17–18% wet basis (w.b.) is considered necessary to avoid fermentation during short-term storage. Therefore, pre-drying is necessary to prevent deterioration in the quality of freshly harvested paddy. Moreover, pre-drying can effectively increase the efficiency of a drying system by adjusting the MC of the fresh paddy.

We examined the effectiveness of a simple pre-drying method of mixing dried rice husk or other absorbents with fresh paddy. This paper reports the results of several experiments conducted in Thailand.

II Experiment 1: Mixing dried rice hull with fresh paddy

1. Objective

This experiment evaluates a simple and low cost pre-drying method of mixing dried rice husk with fresh paddy to maintain the quality of fresh paddy. Rice husk can be easily separated from paddy by using a blower and other low-cost material. This experiment aimed to elucidate the effect of mixing rice husk with fresh paddy and to determine the suitable weight ratio of the mixture based on the MC of fresh paddy and the drying process.

2. Materials and Method

(1) Fresh paddy (Indica Khokhong 23) with an MC of 20% w.b. and rice husk with an MC of 11% w.b. were mixed in small sealed vessels of 600 cc capacity. The mixtures’ volumetric ratios were changed to 0.8, 1.0, 1.2, 1.5, and 1.8 w.b.
and maintained at a constant temperature of 37°C. The MC of the paddy in each vessel was measured and the weight of each mixture was measured approximately within 5 min every 1 h.

(2) Fresh paddy (270 kg) with an MC of 27.7% and dried rice hull with an MC of 11.8% were mixed in grain bags that had a 1.0 m³ capacity; the mixture was adjusted to the volumetric mixture ratio of 1.0 and 1.5 of fresh paddy and dried rice hull, respectively. The internal temperature of the bags was measured by a data logger (Iwasaki Co., Ltd., Bringo) every 1 min using K-type thermocouples, and the MCs of the paddy were measured by a single-kernel moisture meter (Shizuoka Co., Ltd., CTR-200E) for 20 h. The MCs of the samples were accurately calculated by preheating at 105°C for 24 h to obtain dry matter.

3. Theoretical equations

Assuming that the total weight of the mixture does not change, the equation used to determine the weight ratios are:

\[
W_{dh} \cdot M_{D0} + W_{dh} \cdot M_{D0} = W_{dh} \cdot M_{DE1} + W_{dh} \cdot M_{DE2}
\]

where \( W_{dh} \) dry matter; \( M_{D0} \), moisture content [dry basis (d.b.), decimal]; \( M_{DE1}, M_{DE2} \) EMC; \( M_{D0} \) initial MC; suffix 1, 2, materials \( (W_{dh} + W_{dh}) M_{D0} = W_{dh} \cdot M_{DE1} + W_{dh} \cdot M_{DE2} \)

where \( M_{D0} \) average EMC

Then, difference between \( M_{DE1} \) and \( M_{DE2} \) is:

\[
M_{DE1} - M_{DE2} = W_{dh} (M_{DE1} - M_{DE2}) (W_{dh} + W_{dh})
\]

\[
M_{DE1} = W_{dh} (M_{DE1} - M_{DE2}) (W_{dh} + W_{dh})
\]

Difference (Hysteric between \( M_{DE1} \) and \( M_{DE2} \)) is functional to the temperature \( t \) [°C] (Murata et al. 1988) and is approximately revealed as

\[
H = M_{D0} - M_{DE2} = a_1 - b_1 \cdot t
\]

By the experiment of equilibrium of paddy, \( a_1 = 1.5, b_1 = 0.04 \). Then, \( M_{D0}, M_{DE2} \) are

\[
M_{DE1} = W_{dh} (M_{DE1} + W_{dh} + M_{D0} + W_{dh} \cdot H (W_{dh} + W_{dh})
\]

\[
M_{DE2} = W_{dh} (M_{DE1} - M_{DE2}) (W_{dh} + W_{dh})
\]

At a constant storage temperature, \( M_{DE1}, M_{DE2}, M_{D0} \) are constant and the average \( M_{D1} \) is calculated by the following well-known experimental equation

\[
M_{D0} - M_{DE2} = (M_{DE1} - M_{DE2}) \exp(-K_1 \cdot \theta)
\]

where \( K_1 \) [h⁻¹] is the drying constant of paddy, which is functional to the temperature as shown by the Arrhenius equation. \( \theta \) is time [h].

\[
K_1 = C_1 \exp(-C_2/T_p)
\]

\( T_p \) (absolute temperature of paddy, [K]), \( C_1, C_2 \) are determined by drying experiments using different constant temperatures. The results obtained are:

\[
C_1 = 943170, C_2 = 4792
\]

EMC of Indica paddy is calculated by Henderson’s equation.

\[
1 - rh = \exp(-k T_p M_{DE1})
\]

\[
k = 6.093 \times 10^{-6}, n = 2.318; rh; relative humidity [decimal].
\]

4. Results and discussion

(1) The result of the experiment involving the mixing of fresh paddy with dried rice husk in small vessels is shown in figures 1 and 2. The EMC of paddy mixed with rice hull decreased as the mixture ratio of rice hull increased. The MC of paddy decreased exponentially and 50–60% of the MC decrease occurred within 5 h. The calculated value of MC using equation (8) provided a good approximation of the measured value. This shows that the EMC of the mixture can be calculated using the initial MC of the materials and the dry matter weight ratio (equations 7, 8). This method can also be adopted to calculate the change in the MC of the mixture, EMC, and the equilibrium humidity of atmospheric air, which is equivalent to the MC of the mixture.

Using equations (6) and (7), the EMC of paddy and absorbent (rice husk) can be calculated based on the initial MC of the mixture, mixing ratio, and storage temperature. Figure 3 shows the average EMC of paddy and rice husk and the equilibrium humidity calculated based on the volumetric mixing ratio of rice husk with an MC of 5%. Accordingly, the EMC of the mixture with an initial MC of paddy at 21\% w.b. and rice husk at 5\% w.b. is calculated to be 17.5\% w.b., and
The equilibrium humidity is found to be 91% RH. As shown in figure 3, the adequate mixture ratio of rice husk should be more than 1 (which is the maximum mixture ratio) if the initial MC of the paddy is more than 20% w.b. to lower the EMC to 17%.

(2) According to the experiments conducted at certain drying traders, the MC of fresh paddy was 27% w.b. and the MC of dried rice husk that was mixed at the volumetric ratio of 1.0 and 1.5 was 7% w.b. After 20 h, the MC of paddy was 26.1% w.b. at a mixture ratio of 1.0 and 25.4% w.b. at a mixture ratio of 1.5. The air temperature and humidity inside the bags was approximately 35°C and 96% RH, respectively. Both bags of paddy underwent fermentation. Therefore, we concluded that it is necessary to lower the initial MC of the paddy to below 20% because the ability of the rice husk to absorb water from fresh paddy is poor due to its low density.

The average daytime temperature in Thailand is approximately 37°C, the average humidity is 85%, and the EMC of this aerial to paddy is almost correspondent to 16.5%. It is necessary to almost double the mixture ratio to lower the EMC below 17% when the initial MC of fresh paddy is 21% (figure 3). The initial MC of fresh paddy should be lowered below 20% by ambient air ventilation or sun radiation on concrete ground (if dried rice husk is used as the absorbent with a mixture ratio below 1.25, which is considered to be the maximum ratio that can be used).

III Experiment 2: Mixing dried paddy with fresh paddy

1. Objective

When we mixed rice husk with an MC of above 21% with fresh paddy, more than double the volume of rice husk was necessary to decrease the EMC of the mixture below 17% w.b., which is the optimal MC for short-term storage. This would require many grain bags and a large storage capacity. Hence, an alternative, i.e., a denser absorbent is necessary. We therefore evaluated the use of dried paddy as an absorbent.

2. Materials and Method

Fresh paddy (380 kg) with an MC of 20.5% and dried paddy (220 kg) with an MC of 11.6% were mixed in a grain bag of 1.0 m³ capacity (Experiment 2a). Fresh paddy (300 kg) with an MC of 20.9% and dried paddy (300 kg) with an MC of 10.3% were mixed in a grain bag of 1.0 m³ capacity at the volumetric mixture ratio of 1 (Experiment 2b). Changes in MC and temperature were measured as in Experiment 1.

3. Results and discussion

The result of the mixing and drying test in a grain bag of fresh paddy with an initial MC of 20.9% w.b. and dried paddy with an initial MC of 10.3% w.b. is shown in figure 4. After 20 h, at a mixing weight ratio of 0.5, the mixture became nearly equilibrious, and the average MC of the mixture was 15.7% w.b. The individual variation was 0.7% or less and there was no temperature increase in the paddy in both experiments (Experiment 2b; figure 5). This is an easy and low cost pre-drying treatment to conserve grain quality. Figure 6 shows the calculated volumetric mixture ratio and equilibrium humidity based on the assumption that the MC of the initial fresh paddy is the EMC when the initial MC of dried paddy is 12% w.b.

IV Experiment 3: Mixing tapioca pearl with fresh paddy

Figure 3 Average EMC (MEQ) and humidity chart of mixture of fresh paddy (initial MC of 18–22%) and dried rice husk (initial MC 5%) with volumetric mixture.

Figure 4 Temperature at different positions in a grain bag (Experiment 2, Ch5, R40D40; Ch6, R40D10; Ch7, R0D10; Ch8, R0D40).

Figure 5 Temperature at different positions in a grain bag (Experiment 2, Ch5, R40D40; Ch6, R40D10; Ch7, R0D10; Ch8, R0D40).
Figure 6 Calculated volumetric mixture ratio and equilibrium humidity of initial fresh paddy is the same at the EMC when the initial MC of dried paddy initial MC 12% w.b.

1. Objective

Effective absorbent materials are high in density, inexpensive, safe, easy to dry to achieve a low MC, reusable, and easy to separate. While it is difficult to lower the MC of dried paddy below 11%, the MC of tapioca pearl can be more easily lowered and made bowl and can be obtained at a low cost and safe for food. We therefore examined the use tapioca pearl as an absorbent.

2. Materials and Method

(1) Fresh paddy of MC 20.9% w.b. and tapioca pearl of MC 4.5% w.b. were mixed in small sealed test vessels of 600 cc capacity at 8 mixture ratios of 0.3, 0.4, 0.5, and 0.7 (Experiment 3a). Test vessels were kept under a constant temperature of 30°C and weights were measured every 1 h.

(2) Fresh paddy (380 kg) with an MC of 22.2% and tapioca pearl (220 kg) (6 mm φ) with an MC of 11.8% were mixed in a grain bag of 1.0 m³ volume capacity at a mixture volume ratio of 0.4 (Experiment 3b). The internal temperature of different areas of the grain bags and the changes in the MC of each material was measured over 20 h. The MC of the drying paddy and wetting paddy (distinguishable by the difference in their MCs) were determined by a single-kernel moisture meter (Shizuoka, CTR-200E); the MC’s of the samples were accurately calculated by preheating at 105°C for 24 h to obtain dry matter.

Table 1 Size, true density, and bulk density of tapioca pearl, paddy, and rice husk.

<table>
<thead>
<tr>
<th>Absorbent</th>
<th>Diameter (mm)</th>
<th>True density (10³ kg/m³)</th>
<th>Bulk density (10³ kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tapioca pearl (6 mm φ)</td>
<td>5.94±0.50</td>
<td>1389±40</td>
<td>757±20</td>
</tr>
<tr>
<td>(2.6 mm φ)</td>
<td>2.60±0.31</td>
<td>1427±30</td>
<td>771±20</td>
</tr>
<tr>
<td>Paddy (Indica Khokhong 23)</td>
<td>–</td>
<td>–</td>
<td>525±4</td>
</tr>
<tr>
<td>Rice husk</td>
<td>–</td>
<td>–</td>
<td>108±6</td>
</tr>
</tbody>
</table>

3. Results and discussion

(1) In the mixing test in small vessels using dried paddy and tapioca pearl, as the mixture ratio increased, the average EMC of the mixture decreased, and the changes in the MC of the fresh paddy exponentially decreased (figure 9). There was a decrease of about 65% d.b. in MC during the first 4 h (as much of a decrease as during the 20 h interval). The MC lapse rate of paddy during the first 2 h after mixing was commenced was 0.76% w.b./h of tapioca pearl of weight mixture ratio 0.3 (volumetric mixture ratio 0.194) and 1.1% w.b./h of weight mixture ratio 0.5 (volumetric mixture ratio 0.324). These lapse rates were higher than the average MC lapse rate of 0.4–0.6% w.b./h for a hot blast circulation dryer and equivalent to 0.6–1.2% w.b./h for a far infrared radiation.
However, after about 5 h, the MC lapse rate of the mixture decreased to 0.2% w.b./h or less. The EMC of the mixture was almost equal to the average MC [% d.b.] of the weight ratio of the mixture as calculated by equation (2). This shows that the difference between the EMC of the mixture is small. A volumetric mixture ratio of 0.5 is sufficient for an EMC of a mixture of 17% or less in which there is little fermentation and spoilage.

The changes in MC of the mixture in the small testing vessels approximated those calculated by the simulation model of mixing, storage, and drying, and the drying process such as MC. The humidity inside the bag can be estimated using the results depicted by the line graph (figure 10).

The relationship between the mixture ratio and the EMC of the mixture is calculated and depicted in figure 11 (initial MC of tapioca pearl is 8%).

(2) The result of the mix drying test in a grain bag of fresh paddy with an initial MC of 22.2% w.b. and tapioca pearl with an initial MC of 11.8% w.b. is shown in figure 12. The MC profile of the mixture of fresh paddy and tapioca pearl in a grain bag is shown. The mixture reached equilibrium after 20 h and the final average MC of the paddy was 19.4% w.b. and that of absorbent paddy was 19.2% w.b. The calculated EMC of paddy was 19.1% w.b., which was very similar to the experiment. The difference in MCs at different places in the bag was small. The variation between individual parts was slightly 1%. While the internal temperature of the bag did not rise, the EMC was higher than 17%. As shown in figure 11, the mixing ratio should be more than 0.5.

Mixed tapioca was separated from paddy using a fluctuation style separator (roughing vessel) with an efficiency of 0.8 t/h. A screen separator with a sieve size of 6.5 mm was able to separate 90 kg of the paddy and tapioca pearl mixture in 11 min. However, some particles of tapioca pearl are broken during separating process. it is necessary to improve its firmness to ensure its reusability.
V Summary and Conclusions

(1) When rice husk is used as an absorbent that is mixed with fresh paddy with a high MC (above 20%), more than double the volume of rice husk is required to decrease the EMC of the mixture to below 17% w.b., which is the optimal MC for short-term storage of such mixtures.

(2) Changes in MC of mixtures in small testing vessels were similar to those calculated by the simulation model for mixing, storage, and drying which was made and drying process such as MC, inside humidity in layer becomes to be able to be beforehand estimated according to this model.

(3) The EMC of a mixture of dried paddy and tapioca pearl was similar to the average MC of the weight ratio of the mixture. A volume mixture ratio of 0.5 was sufficient for the EMC of the mixture to decrease below 17%.

(4) Mixing dried rice and fresh paddy is a simple and effective method for pre-drying to maintain grain quality. Tapioca pearl is effective as an absorbent; however, it is necessary to improve its firmness to ensure its reusability.

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References


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