EFFECT OF PRE-CONDITIONING TREATMENTS ON SOME MILLING CHARACTERISTICS OF BROWN RICE
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ABSTRACT
Milling characteristics of two rice varieties were evaluated as a function of conditioning process just before milling operation. The grain temperature in the range of 10 to 35°C and grain moisture content in the range of 12.5 to 16.1% (wet basis, w.b.) as a pre-milling treatments of brown rice were used. Conditioned grains was heated for 5 min in the conditioner and non-conditioned grain was heated for two hours in the isothermal chamber. Mathematical models describing the change of grain rigidity as dependent variable with grain temperature and moisture content as independent variables were studied. The results indicated that, in the ideal ranges of brown rice, crushing rigidity for long-grain is 5 - 6kg and for short-grain is 6 -7kg. The most appropriate brown rice temperature and moisture content ranges are 15 - 20°C and 13.5 - 14.1% for long-grain variety and for short-grain variety, they are 15 - 25°C and 14.1 – 15.2%, respectively in view of milling quality. The results also showed that broken milled rice was reduced by 21.7% for long-grain variety and by 31.3% for short-grain. However, the power consumption reduced by 7.14% for long-grain and by 9.6% for short-grain as a result of pre-conditioning treatment of brown rice. The developed mathematical models were highly accurate and can be used to describe the milling characteristics of brown rice as a function of moisture content and gain temperature during milling processes.

INTRODUCTION
Whitening of rice involves removing the bran, germ and the endosperm (leaving white rice), and the removing broken kernels and other defects. This process has to be accomplished with care to prevent excessive breakage of kernel and improve of yield. Fouda 2005 reported that the extent of losses on the edible portion during whitening processes depends

on so many factors as variety of rice, condition of brown rice, the degree of milling required and the kind of rice mill used. Also, the low moisture content of stored grains cause an economic loss since the producers gross income is directly reduced by selling less to a weight with over-dry grains.

In the large-scale rice mills in Japan, temperature and moisture content of brown rice are conditioned as a pre-milling conditioning process from 1975. Milling characteristics are greatly affected by the rigidity of brown rice, which is determined by temperature and moisture content of brown rice during milling process. Kato 2000 reported that the pre-conditioning process has improved the weak point of the brown rice. It warms and moistens only the surface of the brown rice just before milling operation and softens down to the aleurone layer without lowering the rigidity of brown rice. He also reported that, the pre-conditioning process decreases moisture loss and the broken rice generation during the milling operation.

In the experiment, Shi-gang et al. 2005 reported that the brown rice whose moisture content was 12.5% was used as raw material. The brown rice was grouped, then moisturized differently and milled. While milling, the energy consumption, the rate of broken rice and the crack rate were tested. It is confirmed that the stress crack owing to the moisture added to the brown rice can be avoided when the moisture amount added once is limited to no more than 1.5%. It is also proved that the energy consumption can be reduced, the yielding rate of rice can be increased and the quality of rice can be improved. Shi-gang 2006 studied the relationship between the different moisture content of brown rice and the energy consumption, the broken rice rate, the crack rate and the head rice yield. It could be concluded that the head rice yield increased at first falls and then decreased along with the raise of moisture content and it could reach the maximum value (70.78%) when moisture content was 15.5%. The energy consumption of rice milling decreased along with the increase of moisture contents. The broken rice rate fell at first and then increased along with the raise of moisture contents and it could reach the minimum value (4.28%) when the moisture content was 15.5%. In the early study of milling conditions and breakage, Autrey et al. 1955 found...
that if the grain was allowed to cool between milling operations, particularly after the second cone passage, breakage was reduced. The difference between the temperature of the rice entering the mill room and the temperature of the mill room itself could be correlated with the resulting percentage of whole grain rice. The best yields of whole rice were obtained when the rough rice and mill room temperature were the same. They also indicated that the mill room atmosphere was maintained at relative humidity of 70 to 80%. The same authors observed that the variety also caused differences in milling characteristics. Five to eight times more pressure was needed to mill medium-grain (Zenith variety) than Long-grain (Bluebonnet variety) to the same degree of whitening. 

Childers et al. 1975 studied the effects of aerating during milling in a McGill No. 3 batch type mill. They reported that aeration lowered the temperature of the rice during milling. In tests with long-grain rice, head yields increased from 2.0 to 4.5% with aeration. When the rice heats up during milling, the vapor pressure of the water in the rice increases which results in a higher rate of water transfer from the rice kernel to the surrounding air. Aerating the rice during milling reduces the rice temperature and removes heat, which would otherwise be available to evaporate the rice moisture thereby reducing the rate of moisture transfer and the resulting stresses due to the moisture gradient. Fan et al. 2000 indicated that variety, harvest moisture content, drying conditions, and drying duration had significant interactive effects on the head rice yield reduction during drying. Bautista and Sibenmorgen 2002 revealed that the removal of bran as the milling duration and grain moisture content increased resulted in linear reduction of whole kernel yield. Also, Kamst et al. 2002 indicated that compressive strength of rice grain increased by increasing deformation rate and decreased by increasing grain temperature and moisture content. There is limited information available regarding the influence of the pre-conditioning treatments of brown rice grain such as temperature and moisture content changes just before milling process on the milling characteristics under local conditions. Therefore, the objective of the present research was to quantify the effects of brown rice pre-conditioning treatments on the milling characteristics and power consumption of two local rice varieties.
MATERIALS AND METHODS

Experiments were carried out during harvest season of 2006 at Rice Mechanization Center, Meet El-Dyba. The samples were collected from the Experimental Farm of Rice Research Center, Sakha, Kafr El-Sheikh Governorate.

**Harvest:**
Two rice varieties were used: long-grain variety (*Egyptian Yasmin*), which was harvested at initial moisture content of 18.5% (w.b.) and short-grain variety (*Sakha 104*) harvested at initial moisture content of 19.8% (w.b.). After harvest, 20kg of rough rice from each variety, immediately, transported to laboratory of rice mechanization center and cleaned using a dockage tester.

**Drying:**
To prevent the influence of drying methods on the quality characteristics of rice grains, the rice samples was spread out in a thin layer of 2cm thickness at room temperature under shade at average temperature of 22±2°C and variable humidity until reached to the desired moisture contents of 16.1, 15.2, 14.1, 13.5 and 12.5% through two days. This method of drying was considered as a standard method for grain drying as reported by *Hindey et al. 2001*. When the sample reached each level indicated before, 4kg from each variety was placed in closed plastic bags and stored until testing.

**Grain moisture content:**
A kett moisture meter *Model (SP-1D)* was employed to measure the rice moisture content with accuracy of about ±0.1%. The meter was calibrated using the standard moisture measuring method at 130°C for 24 hours as recommended by *AOAC 1990*.

**Hulling:**
After drying to the desired moisture levels, each rough rice variety was hulled using a satake rubber roll husker, *Model (ST-50)*. The brown rice samples were placed in closed plastic bags and stored at 4°C until testing.

**Pre-milling conditioning treatments:**
The sample of brown rice from each variety at average grain moisture content of (12.5, 13.5, 14.1, 15.2 and 16.1%) heated for 5min in conditioned chamber to reach the desired temperatures just before
milling tests were running and used as conditioning treatment. The mass of sample for each treatment was 100g from each variety and three replications were applied. Air conditions were controlled by a commercial temperature and relative humidity controlled air unit (*Model AA*, Parameter Generation and Control, Inc, Black Mountain, NC). The conditioning air is supplied to the conditioned camber consists of six (25cm diameter) circulated screen-bottomed trays arranged as a column. For each treatment, the brown rice samples was spread uniformity into each tray to form a thin layer (one grain). The samples was conditioned by pressurizing the conditioned air space in bottom of the grain layers at the desired temperatures and relative humidity of about 80 - 90%. The temperature and relative humidity of conditioned air were measured by using a digital humidity meter, Chino, *Model (HN-K)*. Also, brown rice samples from each variety and grain moisture content was input in incubator (as isothermal chamber) and heated for two hour to reached the desired temperatures (10, 15, 20, 25, 30 and 35°C) just before milling tests were running and used as non-conditioning treatment as reported by *Kato 2000*. Temperature and moisture content levels achieved in the experiment varied slightly from the design.

**Milling:**
To determine the milling quality resulted from the pre-conditioning process, the resultant brown rice was milled for 30s using the laboratory-polishing machine *Model (SKD-BKK)*. A laboratory grader *Model (TRG-50)* was utilized for separating head rice from the broken. Head yield of milled rice and broken percentage of milled rice were calculated for each treatment as reported by *Shoughy 2001*.

**Rigidity and degree of whitening measurements:**
Hardness meter *Model (Ky-140)* was used to measure the bending and crushing rigidity of rice kernels. The maximum force that applied by the piston to the kernel is 20kg. The degree of whiteness of milled rice samples was measured for each treatment using a Satake digital meter *Model (MM-1B)* as indicated in *Shoughy 2001*.

**Power Requirement:**
The electric power consumption for each test was measured by using an electrical meter, *model (GG 150E)* which connected at the source of power supply as reported by *Shoughy 2001*.

**The Statistical Analysis:**
The analysis of variance and multiple regression analysis were employed in this experimental work to study the effect of conditioning treatments such as grain temperature and moisture content just before milling on the milling quality and energy consumption of two local rice varieties.

**RESULTS AND DISCUSSION**

1. **Rigidity of conditioned and non-conditioned brown rice at different grain temperatures and moisture contents:**

   Figure 1 shows the relationship between bending rigidity of conditioned and non-conditioned grains of two brown rice varieties at different temperatures. The results showed that increasing grain temperature from 10 to 35°C tends to decrease grain rigidity from 6.7 to 5.2 kg and from 6.4 to 4.7 kg for long-grain variety and from 7.2 to 5.7 kg and from 6.9 to 5.1 kg for short-grain variety with conditioned and non-conditioned brown rice, respectively. This means that brown rice which has low temperature is hard to mill since the grain rigidity stays high. Figure 2 and 3 show the relationships between bending and crushing rigidity of conditioned and non-conditioned grains at various moisture contents for long- and short-grain rice varieties. The results showed that, bending and crushing rigidity values of brown rice for conditioned grain were higher than that for non-conditioned grain. While, for long-grain rice variety, it was less than that for short-grain rice variety. Increasing grain moisture content from 12.5 to 16.1%, tends to decrease bending rigidity from 5.5 to 3.8 and from 5.2 to 3.1 kg and crushing rigidity decreased from 6.6 to 4.3 kg and from 6.3 to 3.9 kg for long-grain rice variety with conditioned and non-conditioned grains, respectively. Also, bending rigidity of short-grain rice variety decreased from 6.1 to 4.2 kg and from 5.6 to 3.6 kg and crushing rigidity also decreased from 7.2 to 4.8 kg and from 6.8 to 3.8 kg with conditioned and non-conditioned grain, respectively. This result is due to improve the weak point of the brown
rice as a result of pre-conditioning process. This result was agreed with the results obtained by Kato 2000 and Kamst et al. 2002.

2. The relation between crushing rigidity of conditioned and non-conditioned brown rice at different temperatures and moisture contents:

The relations between crushing rigidity \((CR, \text{kg})\) of brown rice and temperature \((T, ^\circ\text{C})\), moisture content \((M, \%)\) at conditioned \((CR_c)\) and non-conditioned \((CR_{non-c})\) grains of the long- and short-grain rice varieties were expressed in the following formulas:

1. For long-grain rice variety and conditioned grains:
   \[
   CR_c = 14.995 - 0.065T - 0.58M \quad (r^2=0.976, S_E=0.151)\]
   and for long-grain rice variety and non-conditioned grains,
   \[
   CR_{non-c} = 15.107 - 0.685T - 0.602M \quad (r^2=0.97, S_E=0.177).
   \]
2. For short-grain rice variety and conditioned grains
   \[
   CR_c = 20.268 - 0.105T - 0.858M \quad (r^2=0.953, S_E=0.328)\]
   and for short-grain rice variety and non-conditioned grains,
   \[
   CR_{non-c} = 19.96 - 0.103T - 0.857M \quad (r^2=0.945, S_E=0.354).
   \]

Where: \(r^2\) = the coefficient of determination, \(S_E\) = the standard error.

From these equations, it can be seen that crushing rigidity of brown rice is adverse proportion to the grain temperatures and moisture contents. The high grain temperature and moisture content (35°C and 16.1%) resulted in high reduction in grain rigidity for conditioned and non-conditioned grains of two rice varieties. These models adequately predicted the rigidity of brown rice for the conditions tested. The regression equations were highly accurate and can be used to predict the change of grain rigidity of brown rice with the change of temperature and moisture content during milling process under different conditions. Figure 4 shows the relationship between crushing rigidity distribution of conditioned and non-conditioned grains for two rice varieties. The range of brown rice crushing rigidity of long-grain rice is 5-6kg and for short-grain is 6-7kg. The peaks of curves for two varieties of rice approximately correspond to their mean values and show a general specific peculiarity. The mean frequency of the rigidity of two brown rice
varieties are rather in small range, which favorable for the process of milling. In this way it is possible to get better milling process for suitable condition of machine. This result was agreed with the results obtained by \textit{Kato 2000}.

3. Milling quality and power consumption of conditioned and non-conditioned brown rice at different moisture contents:
Milling quality in rice is based on the head rice yield (whole kernels) because this is the milled product of greatest economic value. Figure 5 shows the relationship between the percentage of broken milled rice kernels of conditioned and non-conditioned grains at different levels of moisture contents for two rice varieties. The lowest percentage of broken milled rice kernels (5.4\% and 3.2\%) was found at 13.5\% moisture content of long-grain rice variety and at 14.1\% moisture content of short-grain variety. The broken grains for conditioned grains was less than that for non-conditioned grain for two rice varieties. This result may be due to the rice grain at this level of moisture content is elastic property and can absorb stresses more than the grain at the other levels of moisture content. While, when the grain moisture content changed more or less than this levels, the broken milled rice percentage increased at the same mentioned above factors. For long-grain variety, the percentage of broken milled rice increased from 6.9 to 14.4\% and from 10.3 to 19.9\% by increasing grain moisture content from 12.5 to 16.1\% for conditioned and non-conditioned grain, respectively. While, for short-grain variety, the percentage of broken milled grain was increased from 4.6 to 8.3\% and from 6.2 to 10.8\% with conditioned and non-conditioned grain with increasing grain moisture content from 12.5 to 16.1\%. These results may be due to conditioning the brown rice, just before milling, reduces the rice temperature and removes heat, which would otherwise be available to evaporate the rice moisture thereby reducing the rate of moisture transfer and the resulting stresses due to the moisture gradient. Therefore, the pre-conditioning process decreases the moisture loss and the broken rice generation during the milling operation. The results also showed that conditioned grain have a less values of power consumption than non-conditioned grains for two rice varieties.
Fig. 1: Effect of temperature on grain bending rigidity of long- and short-grain rice varieties for conditioned and non-conditioned grains.

Figure 2: Effect of moisture content on grain bending and crushing rigidity of long-grain rice variety for conditioned and non-conditioned grains.

Figure 3: Effect of moisture content on grain bending and crushing rigidity of short-grain rice variety for conditioned and non-conditioned grains.
Figure 4: Brown rice conditioning and crushing rigidity distribution of long- and short-grain rice varieties.

Figure 5: Broken milled rice kernels of conditioned and non-conditioned grains with different grain moisture contents of two rice varieties.

Figure 6: Power consumption of conditioned and non-conditioned grains with different grain moisture contents of two rice varieties.

Figure 7: Effect of grain moisture content on whitening degree and head yield of conditioning and non-conditioning brown rice.

(Whitening degree ------, Head yield_____)

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The power consumption reduced by 7.15% for long-grain and by 9.6% for short-grain with conditioned grain at the same grain moisture content of about 12.5% and grain temperature of about 20°C. While, it was decreased with increasing grain moisture content as shown in figure 6. This result may be due to the conditioning process was warms and moistens only the surface of the brown rice and softens down to the aleurone layer which leads to reduce the energy consumption of milling operation.

The results also revealed that whitening degree of milled rice is adverse proportion to the milling yield. Figure 7 shows the relationship between whitening degree and milling yield of conditioned and non-conditioned grains at different brown rice moisture contents of two local rice varieties. The results showed that conditioned grain have a high values of whitening degree and milling yield more than non-conditioned grains for two rice varieties. Also, at the same grain temperature of about 20°C, whitening degree of milled rice increased while milling yield decreased by increasing grain moisture content. For long-grain rice variety, whitening degree increased from 32.1 to 39.9% and from 30.2 to 37.8% while milling yield decreased from 59.8 to 53.5% and from 58.5 to 51.3% for conditioned and non-conditioned grains, respectively. Meanwhile, for short-grain rice, whitening degree increased from 28.2 to 37.1% and from 27.3 to 35.3%, while milling yield decreased from 66.3 to 60.4% and from 64.1 to 58.5% for conditioned and non-conditioned grains, respectively. This result may be due to conditioning process softens down to the aleurone layer which improves the whitening degree and decreases the broken rice generation during milling operation. This result was confirmed with the results obtained by Kato 2000, Fouda 2005 and Shi-gang 2006.

**CONCLUSION**

1. Crushing rigidity of brown rice is adverse proportion to the grain temperature and grain moisture contents.
2. At the base conditions of 12.5% moisture content and 10°C grain temperature, the increase in grain crushing rigidity at least 2.17 and
2.36 times greater than at grain temperature 35°C and 16.1% moisture content for long-grain variety as compared to 3.07 and 3.26 times of short-grain variety for conditioned and non-conditioned grain, respectively.

3. The ideal range of brown rice crushing rigidity of long-grain rice were 5- 6kg and 6 - 7kg for short-grain. The most appropriate brown rice temperature and moisture content ranges were 15 - 20°C and 13.5 - 14.1% for long-grain variety and for short-grain variety, they were 15 - 25°C and 14.1 – 15.2%, respectively in view of milling quality.

4. At the same grain temperature and moisture content, the percentage of broken milled rice was reduced by 21.7 % for long-grain variety and by 31.3% for short-grain variety and power consumption reduced by 7.14% for long-grain and by 9.6% for short-grain as a result of conditioning treatment of brown rice.

5. The regression equations were found and can be used to predict the change of grain rigidity of rice with the change of grain temperatures and moisture content with different milling conditions.

It is believed that, this study may be initiate a large program that is so essential to rice milling industry in Egypt, offers a promising alternative to improve milling quality and also reduce the excessive milling losses.

REFERENCES


الملخص العربي

تأثير معاملات التكييف المبدئة على بعض خصائص التبييض للأرز البني

محمد إسماعيل شوغي

أجري هذا البحث في معمل مركز ميكنة الأرز بامعة الديببة وتم الحصول على عينات من المزرعة البجينة بمركز بحوث الأرز بسما بعد موسم حصاة ٢٠٠٢م بهدف دراسة تأثير

بباحث بمعهد بحوث الهندسة الزراعية - الدقى - الجيزة - مصر.
معاملات التكييف قبل التبييض مباشرة عند درجات الحرارة 10, 12, 15, 17, 20, 22, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70 درجة مئوية (على أساس رطب) على بعض صفات التبييض لصنف الأرز: طول 생명ة (باسم المصري) وقشور الحبوب (سخا) وكذلك الطاقة اللازمة لإجراء عملية التبييض. تم وضع عينات الأرز القياسي من صنف الأرز قبل التبييض مباشرة عند محتويات الرطوبة السابقة. ففي غرفة تكييف بمر بها ماء مكيف عند درجات الحرارة المبينة مع رطوبة نسبة في حدود 80/0 % لمدة 50 دقيقة كمعاملة تكييف. وكذلك تم وضع عينات أخرى من الأرز القياسي في غرفة معزولة حراريًا لمدة ساعات كمعاملة بدون تكييف. تم إجراء عملية التبييض للعينات المختلفة وقياسات الجودة وتحليل الاستنباط والنتائج الرياضية التي توصف العلاقة بين بعض خصائص التبييض (كعاملات تابع تحصل في درجات الحرارة والمحتوى الرطبي) لصنف الأرز تحت الدراسة.

وكانت أهم النتائج ما يلي:

1. تتباين القوة اللازمة لانهيار حبوب الأرز البنية تدريجياً عكسياً مع درجة حرارة الحبوب والمحتوى الرطبي لها لصنف الأرز تحت الدراسة.

2. عند درجة الحرارة 10 م وتراوح 50 درجة حرارة 12.5٪ زادت صلابة الحبوب المكيفة ضعفين تقريباً عن صلابة الحبوب غير المكيفة عند درجة حرارة 15 م وتراوح 50 درجة حرارة 16.1٪ مع صنف الأرز طويل الحبوب بينما مع صنف الأرز قصير الحبوب زادت صلابة الحبوب بما يعادل 3 أضعاف تقريباً عند نفس الظروف.

3. أعطت الحبوب المكيفة جودة تبييض أفضل من الحبوب غير المكيفة لصنف الأرز تحت الدراسة. وتستحب الظروف المثلى للتبييض لصنف الأرز طويل الحبوب عند درجة حرارة تتراوح بين 15 إلى 20 م وتراوح 50 إلى 12.5٪، بالنسبة للأرز قصير الحبوب تتيح الظروف المثلى للتبييض هي درجة حرارة تتراوح بين 15 إلى 35 م وتراوح 50، 16.1٪، 14.1٪، 12.5٪، 15.2٪.

4. عند نفس درجة الحرارة والمحتوى الرطبي للحبوب اتخذت نسبة الحبوب المكسورة بعد التبييض نسبة 15.7٪ ونسبة القدرة اللازمة للتبييض بنسبة 7.14٪ مع الأرز طويل الحبوب، بينما مع الأرز قصير الحبوب اتخذت نسبة الكسر بنسبة 5.3٪ ونسبة القدرة اللازمة للتبييض بنسبة 9.6٪ نتيجة معاملة التكييف قبل التبييض للأرز القياسي.

5. تم استنباط نماذج رياضية توصيف التغيير في خصائص حبوب الأرز نتيجة التغيير في درجة الحرارة والمحتوى الرطبي يمكن أن تستخدم في وصف التغير في بعض خصائص التبييض عند الظروف المختلفة.

ينصح من هذه الدراسة ضرورة استخدام طريقة التكييف للأرز القياسي قبل إجراء عملية التبييض بغرض رفع كفاءة عملية التبييض وزيادة المحصول الصافي وخفض نسبة الكسر وكذلك خفض القدرة اللازمة لعملية التبييض وبالتالي زيادة الدخل القومي من الإنتاج الزراعي.

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