Improvement of Traditional Parboiling Process

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Abstract

Laboratory scale studies were conducted to improve the traditional parboiling process. Different steaming treatments were given to the paddy with a rice cooker under open and covered conditions. The energy consumption in parboiling, qualities of parboiled rice and the material temperature during pre-steaming, soaking and steaming were measured. The moisture content of parboiled paddy and hardness of parboiled brown rice at different steaming intervals were also measured for inside and surface layers. Faster rise of material temperature during pre-steaming and steaming, and slower material temperature drop during soaking were observed under the covered method. The hardness of parboiled brown rice was higher for the bottom layer than the surface layer and the covered method provided higher value with even less amount of energy being consumed compared to the open method. There is no difference in overall quality indices between two methods. The experimental results reveal that the traditional parboiling process can be improved to reduce energy consumption by adopting the covered method.

[Keywords] traditional parboiling, parboiled rice, quality of parboiled rice, energy consumption

I Introduction

Parboiling is an ancient method of rice processing, widely used in most of the developing countries like Bangladesh. It has a number of advantages but requires more energy and time for cooking of parboiled rice (Kimura, 1994). Parboiling treatments cause about 2.3% grain loss (Haque et al., 1997), although it improves 7-12% of head yield (Kimura et al., 1995). One fourth of the world’s paddy is parboiled (Kar et al., 1999), and the process consumes a considerable amount of energy and labor. The information on the energy consumption in parboiling processes is scarce and so far known there is no study on the energy consumption in the traditional parboiling process and the study on the energy consumption is desired to find the energy effective process.

Until now parboiled rice has been produced by both traditional and modern methods. Modern methods are energy and capital intensive, and are not suitable for small scale operation at the village level (Ali and Ojha, 1976; Bhattacharya, 1990). In Bangladesh, more than 80% of the rice is processed in villages and less than 20% is processed in commercial rice mills (Rahaman et al., 1996). Various methods and devices are being used in the traditional parboiling process. The device consists of pottery to boilers. Among the devices the vessel is the most commonly used traditional parboiling devices at villages, where no cover has been used and assumed to be the cause of heat loss in the process and greater energy consumption (Fig. 1). At present, conservation of energy is an important issue all over the world and the energy consumption is the key feature in traditional parboiling processes. The reduction in energy consumption is very important, as the demand and cost of energy is increasing. With the growing concern about the cost of parboiling and environmental pollution, improvement of traditional parboiling processes is desired to reduce energy consumption in parboiling process, cost of parboiling and to reduce environmental pollution, which must be suitable and affordable at the village level for small scale production. Therefore, laboratory scale parboiling studies were conducted under open and covered conditions using a rice cooker to determine if the traditional parboiling process can be improved

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in terms of energy consumption and rice quality.

II Materials and Methods

1. Materials

The Bellopatna, an indica variety of paddy harvested in 1999 at the Japan International Co-operation Agency (JICA) farm, Tsukuba, Japan, and stored in a refrigerated warehouse at 5°C, was used in this study. One kg of paddy was taken for each treatment to produce parboiled rice of different grades.

2. Methods

Parboiling is a combined effort of soaking, steaming and drying. Single or double steaming process has been used in traditional parboiling process. The double steaming process of direct heating is the most common and widely used process in traditional parboiling for small scale household production where pre-steaming is given to the paddy before soaking with normal water for 24h and then the soaked paddy is allowed for steaming. The double steaming process of direct heating method (shaded part in Fig. 2) was followed in this study under open and covered conditions with a rice cooker. In the case of open steaming, a cover was not used on the rice cooker. Two resistance thermometer sensors (Okazaki, JPT 100) connected with a data logger (Model 436506-20/H8, Yokogawa Electric Corporation, Tokyo, Japan) were placed inside and on the surface of paddy during pre-steaming, soaking and steaming to measure the temperature distribution (change of material temperature) in the process. Figure 3 shows the placement of the sensors and the schematic diagram of a rice cooker.

(1) Pre-steaming

Pre-steaming treatment is given to the paddy to increase the paddy temperature, which helps to increase the soaking water temperature and reduce the soaking time. It was given to the paddy with an electric rice cooker (Model SR-W180, 1.8 dm³, 100 V, 600 W, National Electric Co., Osaka, Japan) which is considered to be a method of direct heating. The vaporization is a stage at which vapor starts to come out from the surface of the paddy in the rice cooker during pre-steaming and steaming. Based on several trial tests, 27.5°C at the paddy surface was assumed to be the vaporization temperature. The treatment time started recording at 27.5°C surface temperature of the paddy. In this study, seven minutes was allowed for pre-steaming (Sarker and Faruk, 1989) with 350 mL water so that 20% of paddy was submerged in the water (Haque et al., 1997).

(2) Soaking

Soaking is a hydration process, given to the paddy to increase moisture content (MC) up to about 30%, which is required for complete parboiling (Gariboldi,
Soaking was allowed for 24h with tap water at room temperature (Kimura, 1989; Haque et al., 1997). Paddy and water ratio by mass was 1:1.2. After soaking the water was drained with a wire-mesh basket and the weights of soaked paddy and excess water were measured.

3. Steaming

Like pre-steaming, the same electric rice cooker was used for steaming with 430 mL water, so that 20% of paddy was submerged in the water (Haque et al., 1997). Steaming treatment was given to the paddy for a period of 10-30 min (Tiwary and Ojha, 1981) to produce parboiled rice of different grades. Steamed paddy was transferred to a wire-mesh basket to drain the excess water after steaming and then allowed for drying.

4. Water Uptake and Excess Water

The weight of steamed paddy was measured to calculate the apparent water uptake. Apparent water uptake of soaked and steamed paddy was calculated from the ratio of weight gain and the initial weight of the paddy, expressed in percentage. The actual water uptake at different steaming intervals was also determined for surface and inside layers. A small wire-mesh basket (Fig. 4) was used to pick up the sample from the inside layer and a spoon was used to collect the surface sample. The excess water remained after soaking and steaming was also measured to calculate the amount of excess water and express it in volume percent.

5. Drying

In traditional parboiling, drying treatment is given to the paddy for 1-2 days in sunlight. Parboiled paddy produced in this study was shade dried at room temperature. So energy consumption in drying process was not considered in this study. It was dried in two stages: first it dried up to 18-20% (w.b.) of MC and then was heaped overnight for steeping (Haque et al., 1997). Finally, it was dried to about 14% (w.b.) of MC to get better quality and higher milling yield (Bhattacharya and Swamy, 1967; Rahaman et al., 1996).

3. Quality Indices of Parboiled Rice

1. Moisture Content

The MC of replicated samples was determined by the air oven method at 105°C for 24h.

2. Hardness

The hardness of brown rice was measured with a Texture Analyzer TA-XT2 (Stable Micro System, Surrey, England), using a solid cylindrical probe and the diameter was 2 mm. A load cell of 245.2 N was used for hardness measurement. The rice was put on the sample table at the center of the probe in flat position (Kimura, 1991) to measure the peak force (Fig. 5) in Newton (N) at a crosshead speed of 0.1 mm/s which is considered to be the hardness. It was replicated twenty times for each sample using 20 different rice kernels and the average value is reported.

3. Color and Lightness

The L*a*b* color space of CIE Lab was adopted and measured with photoelectric color meter (CR-200, Minolta Co., Ltd., Tokyo, Japan), where L* indicates lightness and a* and b* are the chromaticity coordinates. The color intensity of brown rice was worked
out using the following equation (Kimura, 1989).

\[ B = \sqrt{a^2 + b^2} \]  

(1)

where, \( B \) = Color intensity

(4) Head Yield

The MC has a profound effect on the milling out-turns (Rahaman et al., 1996). Dried parboiled paddy was kept in a warehouse for one week to stabilize the MC and then put in a humidity cabinet (LHL-113, Tabai Espec Corp., Osaka, Japan) for one week at 25°C and 60% relative humidity to homogenize it for all samples which helps to avoid any effects of moisture content on de-husking. The dried parboiled paddy was de-husked with an impeller-type rice husker (FCS type, Otake Co., Oharu, Japan). After de-husking, the brown rice was also placed in the humidity cabinet again for one week before milling. The brown rice was milled with a vertical friction-type milling machine (VP-31T, Yamamoto Co., Tendu, Japan) and the same milling treatment was given to all samples i.e, two passes were given for each sample with same flow rate. A cylinder-type test rice grader (TRG type, Satake Co., Higashihiroshima, Japan) was used to separate the broken grain from whole grain (head rice). The yield was calculated in respect of paddy weight and expressed in percentage.

(5) White Belly

One teaspoon of milled parboiled rice was taken for each sample to measure the white belly. It was calculated by dividing the number of white-bellied kernels by the total number of kernels and presented in percentage.

4. Energy Consumption

The energy consumption in this parboiling process (pre-steaming and steaming) was calculated with the following equation. The decimal efficiency of 0.9 was used (Mirasgedis et al., 1996).

\[ E = \frac{Pt}{f} \]  

(2)

Where, \( E \) = Energy, kWh

\( P \) = Power of the rice cooker, kW

\( t \) = Time, h

\( f \) = Electrical efficiency, decimal

III Results and Discussion

1. Processing Conditions: Pre-steaming, Soaking and Steaming

Sufficient and effective soaking is very important in improving the parboiling process. Pre-steaming treatment improved the material temperature which increases the soaking water temperature and helps to reduce the soaking time (Bhattacharya, 1985; Sarker and Faruk, 1989). In this study, the MC of soaked paddy was found to be above 30% which is required for complete parboiling (Gariboldi, 1974) for both methods. The apparent water uptake was higher for covered soaking and steaming, indicating the higher hydrating velocity which was caused by the higher processing temperature (Bhattacharya and Rao, 1966; Kimura, 1983; Rao et al., 1997). The apparent water uptake after soaking and pre-steaming was found to be higher under the covered method. More excess water was found after soaking and steaming in the covered method compared to the open method, probably because of heat and steam conservation in the process. Therefore, the covered method could reduce the processing time of traditional parboiling. Table 1 shows different treatment parameters and their effect on parboiling.

A similar trend of temperature distribution was observed in all treatments of this study and it is reported only for T2 and T5. Faster rise of material temperature during pre-steaming and steaming was observed in the covered method, supporting the earlier statement to reduce heat and steam loss in the process. Slower material temperature drop was found during the soaking under covered method, which indicates conservation of heat and steam in the process. Figure 6 shows the temperature distribution during the pre-steaming, soaking and steam-

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**Table 1** The Parboiling Conditions and the Water uptake after Soaking and Steaming

<table>
<thead>
<tr>
<th>Treatments and conditions</th>
<th>Paddy MC % (w.b.)</th>
<th>Pre-steaming, min</th>
<th>Steaming, min</th>
<th>*Water uptake, %</th>
<th>Excess water, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Vapor stage</td>
<td>Steaming</td>
<td>Vapor stage</td>
<td>Soaked paddy</td>
</tr>
<tr>
<td>T0 Open</td>
<td>15.0</td>
<td>9.4</td>
<td>7</td>
<td>14.3</td>
<td>10</td>
</tr>
<tr>
<td>T0 Open</td>
<td>15.0</td>
<td>9.5</td>
<td>7</td>
<td>13.6</td>
<td>20</td>
</tr>
<tr>
<td>T0 Open</td>
<td>15.0</td>
<td>9.4</td>
<td>7</td>
<td>14.7</td>
<td>30</td>
</tr>
<tr>
<td>T0 Covered</td>
<td>15.0</td>
<td>8.0</td>
<td>7</td>
<td>11.3</td>
<td>10</td>
</tr>
<tr>
<td>T0 Covered</td>
<td>15.0</td>
<td>8.5</td>
<td>7</td>
<td>11.1</td>
<td>20</td>
</tr>
<tr>
<td>T0 Covered</td>
<td>15.0</td>
<td>8.0</td>
<td>7</td>
<td>11.8</td>
<td>30</td>
</tr>
</tbody>
</table>

Note: * apparent water uptake
Fig. 6 Change of material temperature during pre-steaming, soaking and steaming (1 and 2 show the beginning of sampling to measure hardness and MC for surface and inside layers under covered and open conditions respectively)

Table 2 Quality Indices of Overall Parboiled Rice and Energy Consumption

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Brown Rice</th>
<th>Yield, %</th>
<th>White Belly, %</th>
<th>Energy, MJ/t</th>
<th>Energy Saving, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MC% (wb)</td>
<td>Hardness, N</td>
<td>Color</td>
<td>Lightness</td>
<td>Milling</td>
</tr>
<tr>
<td>T1</td>
<td>10.6</td>
<td>73.8</td>
<td>24.9</td>
<td>60.3</td>
<td>63.1</td>
</tr>
<tr>
<td>T2</td>
<td>10.6</td>
<td>74.2</td>
<td>25.7</td>
<td>59.6</td>
<td>63.3</td>
</tr>
<tr>
<td>T3</td>
<td>10.6</td>
<td>79.6</td>
<td>26.6</td>
<td>59.4</td>
<td>59.5</td>
</tr>
<tr>
<td>T4</td>
<td>10.6</td>
<td>73.0</td>
<td>24.7</td>
<td>62.0</td>
<td>65.2</td>
</tr>
<tr>
<td>T5</td>
<td>10.6</td>
<td>76.4</td>
<td>25.5</td>
<td>60.0</td>
<td>62.3</td>
</tr>
<tr>
<td>T6</td>
<td>10.6</td>
<td>79.7</td>
<td>25.5</td>
<td>57.9</td>
<td>60.4</td>
</tr>
</tbody>
</table>

Note: T1, T2 and T3 are open method; steaming for 10, 20 and 30 min respectively. T4, T5 and T6 are covered method; steaming for 10, 20 and 30 min respectively.

2. Effect of Energy Consumption on the Quality of Parboiled Rice

Table 2 shows the effect of energy consumption on the quality indices of parboiled rice such as hardness, color, lightness, milling yield and head yield.

(1) Hardness

Hardness of parboiled rice is closely affected by the cooking conditions and the gelatinization of rice starch and depends on the degree of parboiling. Higher temperature and duration of parboiling produce harder parboiled rice (Pillaiyar and Mohandoss, 1981; Kimura, 1989). In this study, hardness of parboiled brown rice was increased with the increase of energy consumption for both methods and it varied from 73.0–79.7 N which falls within the suitable range (Islam et al., 2002). Little difference in hardness value was observed between the two methods, which is not significant. The average value of hardness indicates that higher degree of parboiling is achieved under the covered method, although it consumed less amount of energy than the open method.

(2) Color intensity

The color intensity of parboiled rice has a negative impact on the consumer acceptability and loses market value (Bhattacharya, 1985). Treatment conditions affect the color and lightness values of parboiled rice. Higher temperature and longer period of soaking and steaming increase the color intensity of parboiled rice (Bhattacharya and Rao, 1966; Pillaiyar and Mohandoss, 1981; Kimura, 1989). In this study, color intensity is increased with the increase of energy consumption for both methods. It is found to be lower in the case of the covered method.

(3) Lightness

Production of lighter parboiled rice is very important for higher customer acceptance. The lightness of parboiled rice is affected by the processing conditions, steaming temperature and time (Bhattacharya
and Rao, 1966; Kimura et al., 1993). In this study, the lightness value is decreased with the increase in energy consumption for both processes. Initially, the covered method produced lighter parboiled brown rice and it was mixed at the later stage, although the open method consumes more energy and which could be because of the difference in overall treatment time, temperature during soaking and steaming. Therefore, the effect of covered and open method on the lightness value is not very clear. Considering the color intensity and lightness value, which are the important quality indicators of parboiled rice, it can be concluded that the covered method produced better quality parboiled rice than the open method, consuming less amount of energy.

(4) Yield

Parboiling treatments gelatinize the rice starch, improve the hardness of parboiled rice, and minimize the breakage loss, which consequently increases milling yield (Gariboldi, 1974). For this reason, in most of the developing countries, the parboiling process is widely used to improve the milling yield, where food grains are scarce. The covered method provided higher milling and head yield than the open method, although the covered method consumed a lower amount of energy. Hence, an energy conservation measure can be achieved under the covered method and obtain higher milling outturns, which is the main goal of the parboiling treatment.

In this study, 1448.7 MJ/t energy consumption provided higher yield for the covered method, but in the case of the open method, it was 2001.3 MJ/t. Further increase in energy consumption had a negative impact on milling and head yield, due to over-parboiling. It resulted in over-opening of husk components followed by bulging out of the endosperm, which initiates surface scouring during milling and the resultant ground particle lost into bran. On the other hand, incomplete or non-uniform parboiling produces white-bellied rice, which easily breaks during milling and reduces head yield (Sarker and Faruk, 1989). Therefore, this study indicates that higher yield could be obtained under the covered method and obtain higher milling outturns, which is the main goal of the parboiling treatment.

3. Energy Consumption

Energy consumption was found to be lower in case of the covered method than the open method due to difference in overall treatment time between the methods. The material temperature is the key factor in the parboiling process. In respect of treatment time and energy consumption, the covered method produced higher material temperature than the open method. The hardness of parboiled rice is increased with the increase in steaming temperature (Fig. 8) and slightly higher hardness was found in the covered method for both layers, which was caused by the higher material temperature under the covered method.

Hardening is the most important phenomena in the parboiling process. Therefore, the hardness of parboiled rice of the inside and surface layers was also measured at different steaming intervals. Higher hardness, which is an indicator of higher degree of parboiling, was observed for the inside layer than the surface layer for both methods. In this study, maximum material temperature was found to be 100°C. Although the material temperature was not increased above 100°C, the hardness is increased due to the increase in steaming time and energy consumption for both layers and methods. Figure 7 shows the relationship between steaming time and hardness of parboiled rice. The difference in hardness between the inside and surface layer was higher in case of the open method, which also supports that the covered method provides better uniformity of parboiling than the open method. The hardness of parboiled rice is increased with the increase in steaming time and energy consumption for both layers and methods. Figure 7 shows the relationship between steaming time and hardness of parboiled rice.
vaporization time. For 30 min of steaming, it was 2442.0 MJ/t and 2270.0 MJ/t for the open and the covered method, respectively. In the case of the boilerless parboiling where hot soaking was given to the paddy and considered to be a modern method consumed 5862.75 MJ/t (Tiwary and Ojha, 1981). The energy consumption in this study was lower than the reported modern method. This might be because of processing methods, type of energy and the equipment used in the processes.

In this study, the improvement of quality indices under the covered method is insignificant compared to the open method. However, the quality indicators of overall parboiled rice supports that a better quality of parboiled rice can be produced under the covered method utilizing a lower amount of energy. Therefore, from this study it can be concluded that, even if the quality of parboiled rice is not improved, the traditional parboiling process can be improved in terms of energy consumption under the covered method.

**IV Conclusion**

Energy consumption is the key feature in the traditional parboiling process. The reduction in energy consumption is very important to reduce processing time, cost of parboiling and environmental pollution. The test results of this study reveal that by adopting the covered method, the traditional parboiling process could be improved in terms of energy consumption, although the improvement of quality indices is insignificant. The quality indices of overall parboiled rice indicate that the parboiled rice produced under the covered method is better than that of the open method. This study also shows that better uniformity of parboiling is achieved under the covered method, which reduces energy consumption and processing time. Compared to the open method, 7 -11% of parboiling energy could be saved under the covered method, which leads to energy conservation. This would further reduce the cost of parboiling and environmental pollution from the parboiling sector of the developing countries. Therefore, the covered method of parboiling can be used for small scale parboiling at the village level to improve the traditional parboiling process.

**References**


要 旨

伝統的パロイリング加工法を改善するための実験室スケールの研究を行った。電気炊飯器の上部が開閉された条件（開閉条件）と密閉された条件（密閉条件）の2つの方法でパロイリング加工を行った。パロイリングにおけるエネルギー消費量、パロイリング玄米品質、そして前蒸煮、浸漬、蒸煮中の試料温度を制限した。さらに蒸煮における粉層底部と表面の蒸煮時間毎のパロイリング積水分とパロイリング玄米の硬度を制限した。密閉条件では開閉条件と比較して、前蒸煮や蒸煮過程の早い温度上昇、浸漬過程では遅い温度低下が確認された。パロイリング玄米の硬度は粉層表面のものより低部が高く、密閉条件のパロイリング玄米の硬度は開閉条件と比べて高かった。2つの加工条件で製造したパロイリング玄米品質には大きな違いがなかった。密閉条件を適用することによってエネルギー消費量が低減され、伝統的パロイリング加工法が改善できる。

[キーワード] 伝統的パロイリング、パロイリングドライフ、パロイリングドライス品質、エネルギー消費

「技術論文」
伝統的パロイリング加工の改善
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