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Effect of degree of milling on specific energy consumption, optical measurements and cooking quality of rice

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Abstract

This investigation attempts to minimize the degree of milling (D_{OM}) for uniform light colour and superior cooking quality of long, medium and short grain rice varieties. Three *indica* varieties of rice samples were milled to various degrees (2–18%) in Satake laboratory abrasive polisher. The effect of D_{OM} on specific energy consumption (E_S), optical value measured with a Satake milling meter, and cooking qualities were analyzed for the three varieties. Cooking index (CI) was determined as a function of optimum cooking time (C_T), water uptake ratio (W_{UR}), volume expansion ratio (V_{ER}) and length expansion ratio (L_{ER}). E_S, Satake degree of milling (SDM) values and CI increased with progressive milling. Long and slender variety has lower mass loss during milling compared to the short-bold variety and therefore has higher E_S. However, the long-slender variety has higher CI compared to the other two varieties considered in this study. Optimum D_{OM} was determined using Excel solver and by superimposition of graphs, considering the E_S, SDM measurement and CI. The optimum D_{OM} was found to vary between 10 and 13% for the long-slender, medium and short-bold varieties of rice within the acceptable range of optical property, and CI.

Keywords: Degree of milling; Cooking quality; Optical value; Specific energy consumption; Cooking index

1. Introduction

Rice is mostly consumed in whole milled form. Rice milling is a combination of several unit operations to convert paddy into well-milled silky-white rice, which has superior cooking quality attributes (Roberts, 1979). It is a fact that colour and cooking characteristics of the milled rice are the important factors deciding the quality that influence the price of the rice. The majority of the consumers prefer well-milled white rice with little or no bran remaining on the endosperm. Ironically, in countries where rice is the principal food, the consumer preference is normally for highly milled rice. The proteins, fats, vitamins, and minerals are concentrated in the germ and outer layer of the starchy endosperm (Itani, Tamaki, Arai, & Horino, 2002; Juliano, 1985) and these are removed in course of milling operation, thus reducing the nutritive value of the rice. Polishing of rice is the most energy intensive process of all the rice milling operations. Therefore, milling or polishing rice to higher degrees will result in higher energy consumption. Furthermore, in over-milled rice, both the total and whole-grain milling yields are reduced, with a subsequent loss in market value. Increase in D_{OM} reduces the total yield, head yield and increases energy consumption in milling operation, whereas it improves the cooking quality of the resultant rice.

Brown rice kernel has an undulating surface profile, rendering uniform removal of bran a difficult operation. Even after 75% of bran removal, streaks of bran are still left on the furrows (Juliano, 1985). In order to remove bran completely, the rice is often over milled, thereby losing starchy

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Notations

$\dot{D}_{OM}$	rate of bran removal, % D_{OM}/s	L_{ER}	length expansion ratio
CI	cooking index, min^{-1}	SDM	Satake degree of milling
C_T	optimum cooking time, min	t	milling duration, s
D_{OM}	degree of milling, %	V_{ER}	volume expansion ratio
E_S	specific energy consumption, kJ/% D_{OM}	W_{UR}	water uptake ratio
G	predicted germ content, %		

endospermic material along with outer bran layer. Amount of bran in rice kernels varies with variety, environmental conditions and agronomic practices (van Ruiten, 1985). Most of these factors cannot be controlled. Hence different rices require different milling levels.

Cooking quality of rice is important to consumers and is influenced by the variety, cultivation and post harvest practices, D_{OM} and cooking methods (Park, Kim, & Kim, 2001; Perdon, Siebenmorgen, Mauromoustakos, Griffin, & Johnson, 2001). Therefore, the objective of milling has to emphasize on removal of minimum bran; so as to have the acceptable cooking qualities of the milled rice i.e. minimum cooking time, higher water uptake ratio, length expansion ratio and volume expansion ratio. Considering the above points, this research aims at examining the effects of different milling ratio on the energy consumption, optical value and cooking quality and therefore to choose a suitable D_{OM} of the long-slender, medium and short grain *indica* rices for obtaining comparable cooking behaviour and light coloured resultant rice.

2. Materials and methods

2.1. Materials

Freshly harvested, *Pusa Basmati*, aromatic, long and slender variety (procured from Haryana, India) *Swarna*, medium grain variety (procured from local market) and *ADT37*, short and round grain variety (procured from Tamil Nadu, India) were selected for this study. The varieties were dehusked using a Satake rice machine (Type THU, Satake Engineering Co., Tokyo) and stored in double sealed polythene bags at 5 °C in a refrigerator (Quick freezer, 200 l capacity, Remi equipments, India) till the experimentation. Samples were removed from refrigerator 24 h before the experiments to equilibrate the temperature to room conditions. Moisture content was determined using standard air oven method by keeping 5 g of grain in oven at 105 °C for 24 h and then noting the weight and was expressed in percent wet basis. Dimensions of brown rice of each variety were measured manually by Satake Grain Shape Tester (Model-MK 100, Japan) having 0.001mm precision. Measurement was made on 50 well-distributed, randomly drawn grains from the test samples of each variety, after cleaning and grading. Brown rice samples of *Pusa Basmati*, *Swarna* and *ADT37*, were polished in abrasive polisher (Model: Satake Pearler-TM05) for 15–180 s, at the interval of 15 s. The emery disc was of 36 grit size, with a rotor speed of 1360 RPM. The samples were aspirated (Bates Aspirator, USA) and mass loss was noted for three varieties, to calculate D_{OM}. The D_{OM} was determined, using gravimetric methods, by the equation: $D_{OM} = (1 - [\text{weight of milled rice/weight of brown rice}]) \times 100$. Average data of the triplicate samples were used for analysis. Brokens were removed using Satake laboratory rotary grader and only head rice was used for the experimentation. Germs were separated out from the bran fraction by aspiration. Average data of triplicate samples were used in the analysis.

2.2. Energy consumption

Energy consumption in experimental samples was measured by wattmeter (DVS/1065, India). The energy required for operating the machine without load was first noted and it was subtracted from the energy data collected when machine was running under full load. For total running period of the machine, energy was calculated and the specific energy consumption (E_S) of the milled rice sample was calculated using the formula: $E_S = (\text{Energy under full load} - \text{Energy under no load})/(D_{OM})$.

2.3. Optical degree of milling measurement of the sample

Optical value of all milled rice samples, including the brown rice was measured using a Satake milling meter (MM1B, Japan). Prior to this measurement, the milling meter was calibrated using standard white and brown plates according to the calibration procedure recommended by the manufacturer. The instrument utilizes both transmittance and reflectance measurement to determine Satake degree of milling (SDM). Whiteness was measured as the percentage of light reflected from the sample, whereas transparency was the percentage of light transmitted through the samples of standard depth. The SDM was calculated using both the whiteness and the transparency by a factory-installed algorithm in the microcomputer of the milling meter. SDM is displayed as a value from 0 to 199, where a value of 0 represents a SDM level corresponding to brown rice and 199 represents a SDM level of snow-white fully milled rice. Thus, a larger SDM number represents thorough or complete bran removal (Chen & Siebenmorgen, 1997).