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Two stage drying of high moisture paddy with intervening rest period

Abhay Kumar Thakur [a], A.K. Gupta [b,*]

[a] Central Institute of Post Harvest Engineering and Technology (ICAR), Abohar 152 116, Punjab, India
[b] Department of Processing and Food Engineering, College of Agricultural Engineering, Punjab Agricultural University, Ludhiana 141 004, Punjab, India

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Abstract

The artificial methods of paddy grain drying have an effective influence on energy consumption and its quality. The effects of intervening rest periods between the two stages of drying on drying rate, energy consumption and head rice yield were evaluated. During the period of the rest stage, the grain released moisture as an effect of the residual temperature, and also, the grain moisture became uniformly distributed within the kernels. The appropriate moisture ratio at which resting starts and the duration of resting were evaluated by measuring the changes in relative humidity in the head space of the mass of paddy and also from the diffusion coefficient values obtained from the drying rate data. A resting duration between 75 and 90 min at a moisture ratio around 0.715 was found suitable for overall good results in respect of drying, energy consumption and head rice yield. Using the measured moisture data of the first stage, rest period and second stage, a non-linear regression method was applied to an approximate solution of the diffusion equation to estimate the drying rate and, further, the effective diffusion coefficient. A significant amount of energy (21–44%) could be saved by providing a rest period from 30 to120 min between the two stages of drying. Discontinuing the drying process during the rest period above 60 min considerably improved the head rice percent when compared with the results from continuous drying experiments.

Keywords: Two stage drying; Paddy; Rest period; Tempering; Diffusion coefficient; Energy consumption; Head rice yield

1. Introduction

The leading food crop in the world is rice, and it sustains more than half of the world's population [1]. The rice crop forms the basic economic activity directly or indirectly for about 150 million rural house holds in India [2]. Paddy (rough rice) is harvested at high moisture content, usually in the range of 22–30% (w.b). Harvesting paddy with high moisture content normally results in high yields and less damage and prevents field losses due to dropping and shattering. Drying is essential to preserve the paddy grain for a longer period or to

* Corresponding author.
E-mail address: akgupta_pau@rediffmail.com (A.K. Gupta).

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Nomenclature

A_1	constant of approximate solution of diffusion equation (decimal)
d.b	dry basis
D	effective diffusion coefficient/mass diffusivity (m^2/h)
E	energy consumption (kW h/kg moisture)
k	drying rate (min^{-1})
l	characteristic length (radius of infinite cylinder, m)
M	moisture content at any time during drying (% d.b)
MC	moisture content
M_0	initial moisture content (% d.b)
M_e	moisture content at equilibrium (% d.b)
MR	moisture ratio $\{(M - M_e)/(M_0 - M_e)$, decimal$\}$
MR_{rest}	moisture ratio at beginning of rest period (M/M_0, decimal)
r^2	coefficient of determination
s^2	residual mean square
t	drying time (min)
t_h	tempering/resting time between drying stages
w.b	wet basis
λ	characteristic value

process it into white rice. However, drying significantly affects the quality of the rice; and also, this unit operation is known to be energy intensive. Various drying techniques have been experimented in order to improve the rice quality, e.g. low temperature continuous drying for long duration, high temperature drying for short time, thin layer multi-pass/intermittent drying etc. The head rice yield (HRY) depends on several factors, such as variety, harvesting methods, moisture content, drying methods and milling techniques. The difference in HRY of parboiled paddy by drying under hot air at 60 °C and sun drying was insignificant [3]. Severe drying conditions can increase the number of broken rice due to high fissuring [4–8]. The broken rice considerably lowers the market value, and therefore, an effective drying process is required to produce optimal HRY with minimum energy input. Yang et al. [9] determined the moisture content gradients vs. drying durations by finite element modeling and found that the HRY was highly related to the moisture content gradients, which had a maximum value at a drying duration of about 28 min for the rice variety 'Cypress' before declining slowly thereafter, when the rice was thin layer dried at 60 °C and 17% relative humidity (RH) from an initial moisture content of 22.1% (w.b). High temperatures can be used in drying rough rice without consequent reduction in head rice yield as long as proper tempering techniques are employed [7].

Tempering of paddy during the drying operation has become a common practice for reducing breakage percentage in milling. During the tempering period, the moisture concentrated at the centre of the kernel is uniformly distributed by the process of diffusion. A uniform moisture distribution in the kernel increases the drying rate of grain in the next cycle of drying and decreases the internal stress. Besides, the increased rates of drying lower the energy expenditure on the drying operation. Kunze and Choudhury [10] proposed that the moisture gradient created during the drying period provides the potential for later fissuring. Yamaguchi et al. [11] concluded that the thermal stresses in the rice kernel are negligibly small compared with the hydro stresses because the coefficient of thermal expansion is remarkably smaller than that of hygroscopic expansion for rice endosperm. The hydro stress created in continuous drying could be relaxed by providing an intervening rest period. Several studies have been conducted to find the appropriate time required for tempering the grain during the process of drying. In a study of the theoretical and practical aspects of rough rice tempering [12], it was concluded that the most efficient energy utilization during multi-pass drying is achieved if complete tempering (complete moisture equalization) is allowed between drier passes. Tempering times used in commercial rough rice drying may be much longer than necessary. In their simulation studies, for a temperature of 35 °C and other typical drying conditions, tempering was 95% complete in less than 2 h and fully complete