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RESEARCH PAPER

Effect of degree of polishing on physical and milling properties of rice

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SUMMARY :

Investigation were conducted on commercial variety of paddy (Pant Dhan - 4) commonly grown in Northern India. Physical, gravimetric and milling properties were analysed in the laboratory at different degree of polish ranging from 0 per cent to 11.31 per cent. It was observed that the length, width, thickness and 1000 kernel weight ranged from 6.53 mm to 6.13 mm; 2.36 mm to 2.20 mm; 1.84 to 1.76 mm and 27.01 g to 20.00 g, respectively for 0 per cent and 11.35 per cent degree of polish. Milling, head broken yield were significantly affected by degree of polish. The various mathematical models had been developed for expressing the interaction between physical, gravimetric and milling properties with degree of polish were computed.

KEY WORDS : Polishing, Physical, Milling properties

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Paddy (*oryza sativa* L.) is the largest agricultural commodity grown in over 100 countries. India is one of the largest growing countries of the world. Nearly one-third of cultivation area in India belongs to paddy and nearly three fourth of the people in this country subsist on it (Prabhakar *et al.*, 1975). The production of paddy throughout the world is continuously increasing as also the preference of consumers for better quality. This has generated strong awareness among millers to producer high quality milled rice and rice products at most economical costs, resulting in expansion of rice milling industry.

Milling and cooking properties of rice have direct and great influence on its commercial value (Web *et al.*, 1968). The term "degree of milling" or "per cent polish" is a measure of the extent to which pericarp, tegmen and aleurone as well as the germ have been removed on paddy or rice basis (Sidhu *et al.*, 1975). The milling quality is judged by high head rice yield and minimum brokens. Utilization of rice has been based on the knowledge of the composition of the kernel, and has been become extensive. It is well known that milling brings about changes in the chemical composition, the degree of milling determining the amount of nutrient in the residual milled rice. Proteins, lipids, vitamins and minerals are present in greater quantities in the bran removed than in the remaining endosperm (Roberts, 1979). This study was undertaken to investigate the effect of degree of polish on physical and milling properties of milled rice.

EXPERIMENTAL METHODS

Commercial variety of Pant Dhan-4 was procured from University Crop Research Centre. Shelling of pre-cleaned paddy was done through Satake rice sheller. Unshelled paddy was separated manually from brown rice. After separation of unshelled paddy the brown rice of 100 g were milled in a Satake rice polisher for a period of time varying from 0 to 60 s with an interval of 10 s to attain different degree of polish. The corresponding degrees of polish were in the range of 0 to 11.35 per cent. All the brokens grains, in respective of their sizes in the sample were separated from the head rice and accounted as brokens. The counting of the brokens in sample was done after various times of polishing. The length, width, thickness, 1000-kernel (head rice) weight, bulk density and true density were determined for each sample of milled rice (Wratten *et al.*, 1969 and Mohsenin, 1970). Reported values are the average of three replications except length, width and thickness. These values of physical dimensions are the average of 100 randomly selected full grains.

EXPERIMENTAL FINDINGS AND ANALYSIS

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Effect of degree of polish on physical and gravimetric characteristics :

The experimental data on physical and gravimetric characteristic are given in Table 1. The data showed significant variation in all physical dimensions. The mean values of length, width and thickness of paddy varied from 8.65 mm to 10.72 mm, 2.40 mm to 2.92 mm and 2.00-2.35 mm, respectively whereas standard deviation of length, width and thickness was 0.56, 0.18 and 0.09 mm.

Since the brown and milled rice are successive products of paddy resulting from dehusking and polishing operation, it was hypothized that there should be some correlation amongst these characteristics. Table 1 shows the data of length, width and thickness of milled rice at different degree of polish (0, 4, 6.25, 7.93, 9.01, 10.4 and 11.35 %). The range, mean and standard deviation of milled rice varied from 5.99 mm to 7.10 mm, 6.53 mm, 0.34 and 5.73 mm to 6.51 mm, 6.13mm and 0.24,

Table 1 : Data on physical and gravimetric properties of paddy and milled rice at 13±1%(d.b.)

Characteristics	Paddy	Milled rice (% Degree of polish)						
		0	4	6.25	7.39	9.01	10.4	11.35
Length (mm)								
Range	8.65-10.72	5.99-7.10	6.06-6.75	6.07-6.77	5.88-6.68	5.74-6.68	5.8-6.49	5.73-6.51
Mean	9.34	6.53	6.43	6.39	6.31	6.30	6.16	6.13
S.D	0.56	0.34	0.21	0.16	0.23	0.28	0.21	0.24
Width (mm)								
Range	2.40-2.92	2.11-2.54	2.17-2.60	2.10-2.49	2.00-2.49	2.21-2.35	2.21-2.35	2.20-2.39
Mean	2.69	2.36	2.34	2.32	2.27	2.26	2.24	2.20
S.D	0.18	0.12	0.14	0.13	0.052	0.05	0.04	0.032
Thickness (mm)								
Range	2.00-2.35	1.70-2.01	1.63-1.96	1.69-2.90	1.62-1.90	1.54-1.93	1.54-1.93	1.74-1.87
Mean	2.15	1.84	1.84	1.81	1.80	1.80	1.77	1.76
S.D	0.09	0.10	0.10	0.11	0.09	0.12	0.058	0.05
L/W ratio								
Mean	3.47	2.767	2.745	2.755	2.740	2.74	2.677	2.677
W/T ratio								
Mean	1.252	1.283	1.276	1.282	1.275	1.279	1.287	1.25
LWT (mm^2)								
Mean	54.02	28.343	27.691	26.888	26.244	26.138	25.481	25.278
Size (mm)								
Mean	3.78	3.049	3.025	2.996	2.972	2.967	2.942	2.935
1000-Kernel Weight								
Mean	27.53	27.01	24.6	24.4	23.6	22.4	22.2	20.0
Bulk Density (g/ml)								
Mean	0.650	0.707	0.70	0.701	0.701	0.706	0.724	0.726
True density (g/ml)								
Mean	1.19	1.425	1.42	1.419	1.419	1.417	1.416	1.416

respectively as degree of polish varied from 0 per cent to 11.35 per cent on brown rice basis. Where as thickness varied from 2.11 mm to 2.54 mm, 2.36 mm and 0.12; 1.70 mm to 2.01 mm, 1.84 mm and 0.10, respectively for milled rice of 0 per cent.

The variation in the values of apparent volume ranged from 28.343 mm^3 to 23.735 mm^3 for 0 per cent to 11.35 per cent degree of polish, respectively. The size of milled rice was computed as a cube root of length (L), width (W) and thickness (T) for all samples (Mohsenin, 1970). It was observed that the sizes of kernels decreased as the milling/polishing proceeds. Mathematical models (linear, hyperbolic, exponential, logarithmic and power models) were attempted to correlate the physical dimensions of milled rice with degree of polish (D_p). The models which had 'r' value more than 0.800 and low associated errors were accepted (Table 2). This resulted the following models were accepted the experimental observation satisfactorily:

$$L = 6.56\ e^{-0.005\ DP} \quad \text{.........1}$$

$$W = 2.55\ e^{-0.056\ DP} \quad \text{.........2}$$

$$T = 1.94\ e^{-0.038\ DP} \quad \text{.........3}$$

The regression models were also attempted to correlate the length-width ratio and width-thickness ratio of milled rice with degree of polish. It was found that the all attempted models had 'r' value less than 0.800 and associated error high and thus the models were rejected.

The mean values of gravimetric properties of milled rice at different degree of polish are given in Table 1. 1000-kernel weight of milled rice ranged from 27.01 to 20.00 g whereas the weight of paddy kernel was found 27.53 g. The weight of the kernels decreased due to removal of bran from the rice. 1000-kernel weight of the milled rice were correlated with degree of polish and found that the only linear model was the best fit having 'r' value very high (0.956) and the standard error of estimate (SEE) and mean error (E_m) were 0.714 and 2.26, respectively. The linear model is given below:

$$W_k = 27.20 - 0.535\ D_p \quad \text{.........4}$$

The bulk density of milled rice varied from 0.707 g/ml to 0.726 g/ml (Table 1). It was found that the bulk density decreased during the first 30 s of milling and on further milling the bulk density increased. The values of 'r' being less than 0.800 for all attempted models and the associated error were also found quite high. Hence, the attempted model were rejected.

The true density of milled rice varied from 1.425 g/ml to 1.416 g/ml as the degree of polish ranged from 0 per cent to 11.35 per cent, respectively. All above five models were attempted to correlate true density of milled rice with degree of polish. Various mathematical models were tested for their suitability (least error prediction criteria) to describe the phenomenon exponential model was found the most precise having high 'r' value of 0.972 and low value of associated errors (Table 2).

The following exponential model have been developed to correlate the true density with degree of polish.

$$TD = 1.4256\ \exp\ (0.005)D_P \quad \text{.......... 5}$$

Table 2 : Milling characteristics of milled rice of different degree of polish

Time of milling (s)	Degree of polish (%)	Milling yield (%)	Head yield (%)	Breakage (%)
0	0.000	76.860	65.382	11.498
10	4.000	76.100	63.055	13.045
20	6.250	75.790	62.730	13.060
30	7.935	75.450	61.848	13.062
40	9.010	75.210	61.211	13.999
50	10.400	74.910	60.680	14.230
60	11.350	74.770	60.270	14.500

Table 3 : Statistical parameter of reported models

Model	'r'	SEE	E_M
$L = 6.56\ e^{(-0.005)DP}$	0.953	0.007	0.560
$W = 2.55\ e^{(-0.058)DP}$	0.950	0.008	0.006
$T = 1.94\ e^{(-0.038)DP}$	0.935	0.006	0.454
$W_k=27.20 - 0.535\ D_p$	0.956	0.714	2.260
$TD = 1.4256\ e^{(0.005)DP}$	0.972	0.003	0.570
$M_Y = 76.89 - 0.186\ D_P$	0.988	0.044	0.004
$H_Y = 65.23 - 0.438\ D_P$	0.909	0.525	0.638
$BR_Y = 11.62 + 0.250\ D_P$	0.958	0.321	1.520

Effect of degree of polish on milling characteristics :

Milling quality is based on the yield of whole kernel (head) rice having the product of greatest economic value. However, kernel breakage is undesirable side effect of rice polishing. In commercial scale rice milling operation, rice kernel breakage is one of the single most important factor, which affect the economics of the rice milling (Gariboldi, 1986; Sidhu *et al.,* 1975).

The maximum milling yield 76.88 per cent was observed at 0 per cent degree of polish and minimum yield 74.88 per cent at 11.35 per cent which corresponds to maximum polishing of rice. The head yield of milled rice ranged from 65.32 per cent to 60.27 per cent (Table 3). During the first 30 second the head yield was reduced by 5.4 per cent whereas the last 30 second of milling, the head yield reduced only 2.55 per cent.

Breakage of rice kernels in polishing /whitening is an unavoidable phenomenon. One of the main operational factor (other than varietal characteristics) is the average residence time of the kernel with in the polisher which not only affects the magnitude of polish accomplished but also the consequent grain breakage. The cause of breakage of rice grains have been classified as being due to the properties of the grain and to the conditions under which the grain is milled. For quantifying the process of breakage of kernels varies empirical relations were considered and based on the fact that the rate of breakage could either be constant with time or a function of further breakage to take place or be a function of further breakage to take place (Bhatia, 1969). The percentage of brokens increase with increase in polishing time due to friction between the grain. The correlation between milling, head and brokens yields with degree of polish were attempted. The linear regression was considered errors. The following empirical equations were found to describe the process satisfactorily:

$$M_Y = 76.89 - 0.186\ D_P \quad \ldots\ldots\ldots\ldots.. \ 6$$

$$H_Y = 65.23 - 0.438\ D_P \quad \ldots\ldots\ldots\ldots.. \ 7$$

$$BR_Y = 11.62 + 0.250\ D_P \quad \ldots\ldots\ldots\ldots.. \ 8$$

The values of ‘r’, SEE, EM above empirical equations are given in Table 3.

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