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ORIGINAL ARTICLE

Rice Colour Measurement for Various Milling Fractions

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Abstract

Degree of milling is an important quality parameter for rice. The degree of milling is measured by different methods. In the current investigation, 3 varieties of rice were milled for 15 to 180 seconds at every 15 seconds intervals by a laboratory abrasive polisher. The colour values of the rice milled to different degrees were measured using Hunter lab colouri meter and Satake milling meter. Satake transparency and whiteness values increased with degree of milling as bran containing pigments were removed during progressive milling. As the degree of milling progressed the hunter L-values increased from 51.22 to 68.74, 41.01 to 67.87 and 52.88 to 69.5, the a-value decreased from 2.99 to -0.9, 5.38 to 0.49 and 3.28 to -0.95 for Swarna, ADT 37 and Pusa Basmati, respectively. The b-value decreased 16.18 to 14.01 and 16.99 to 14.22 Swarna and Pusa Basmati, respectively, however the values increased from 12.26 to 13.26 for ADT 37. All colour values exhibited polynomial relationship with degree of milling. Satake Degree of Milling (SDOM) was correlated to Hunter L value linearly, except for the red grain ADT 37, whose initial SDOM values were influenced by the red pigment in the bran.

Keywords: Rice, degree of milling, Satake degree of milling, transparency, whiteness, hunter Lab values.

Introduction

Rice is a major staple food in most of the Asian countries. It undergoes various operations such as dehusking, polishing, sorting and grading operations prior to cooking. Polishing pertains to the conversion of brown rice into white milled rice by removal of the bran layer wholly or partly. Rice bran includes the pericarp, seed coat, nucellus, aleurone layer, which are rich in fibre, pigments, oil, protein, polyphenols, vitamins, and minerals to name a few (Mohapatra, 2004). During milling however, the protein and fat rich germ is also removed along with bran. Though, there is growing interest in consumption of brown rice due to awareness regarding its health benefits; a large section of population still prefers well-milled white rice. The reasons could be summed up as follows: (i) both the high oil content in the bran and fibrous material make the brown rice difficult to be digested, especially by human beings, (ii) keeping quality of brown rice as well as under-milled rice is poor, as rancidity is developed due to increase in free fatty acids (Rao *et al*., 1967) thus, adversely affecting the sensory quality (Piggott *et al*., 1991), (iii) brown rice is more susceptible to insect attack than milled rice (McGaughey, 1970), and (iv) the appearance, taste, cooking and textural quality of rice improves on milling (Roberts, 1979; Mohapatra and Bal, 2006; 2007; Bett-Garber *et al.*, 2012).

About 7-8 % of milling usually gives good appearance to rice grain but Government of India has recommended 4-5 % milling only (Mohapatra, 2004), in order to save more material, and vitamins which would otherwise be removed with bran. Since brown rice has an undulating surface, during milling operation there is more mass loss from the ridges than from the furrows (Lamberts *et al*., 2007). For under-milled rice, the residual pigments and bran still remain in the furrows of the grain. In order to get rid of the residual bran and pigments, rice is over milled, where some portion of starchy endosperm is removed along with bran.

Investigation on methods of evaluation of degree of milling has been under attention for quite some time. These have been mainly concerned with the development of objective methods, which were either chemical, or physical in nature. Chemical methods that have been suggested include techniques for quantitative estimation of chemical constituents of bran and qualitative differential dye–staining techniques (Bhattacharya and Sowbhagya, 1972). Among the physical methods, optical and gravimetric techniques are found to have been extensively used. With the technological development, fast methods of determining the degree of milling are also being adopted by checking the surface appearance of the grain. Light reflectance meter (Johnson, 1965), near infrared (NIR) spectroscopy have been used to quantify the residual lipid content to predict rice degree of milling (Kao, 1986; Wadsworth *et al*., 1991; Chen and Siebenmorgan, 1997; Saleh *et al*., 2008). Gras *et al*. (1990) compared Mintola CIE colour values with Hunter Lab colorimeter for milled rice. Siebenmorgen and Sun (1994) and Mohapatra and Bal (2006) measured the degree of milling using a commercial milling meter. Machine vision system has also been deployed to estimate rice degree of milling by correlating it with grey scale values (Fant *et al*., 1994; Liu *et al*., 1998; Yadav and Jindal, 2001).

Since degree of milling affects the marketability and safe keeping of the milled rice, it is imperative for the rice millers to mill rice to a suitable degree without adversely affecting the nutrient value. Considering the above points, this investigation was aimed at determining the effect of milling on the colour values of three different *indica* rice milled to different fractions and to establish a relationship between the colour values measured in two different commercial colour measuring systems.

Materials and Methods

Pusa Basmati, aromatic, long and slender variety (procured from Sonepat, Haryana, India), Swarna, medium grain variety (procured from local market, Kharagpur, WB), ADT37, short and round grain variety (procured from Tamilnadu, India) were selected for this study. All the paddy varieties were at moisture content of 13.5 % ±0.2 (w.b.). The test samples were cleaned and stored in a closed metal bin. The varieties were dehusked and stored in double sealed polyethylene bags at 5°C in a refrigerator till the experimentation. Samples were removed from refrigerator 24 h before the experiments to equilibrate the temperature to room conditions.

Polishing of rice

The paddy samples were cleaned and dehusked using a laboratory aspirator (BGN, H.T Mc Gill Co. USA) and rubber roll dehusker (THU 35A, Satake, Japan), respectively. The brown rice was then polished for 15 to 180 s, at an interval of 15 s, to obtain different milling fractions using an abrasive type polisher (Satake Laboratory Pearler TM-05, Japan). Rice degree of milling was determined by gravimetric method as: Degree of Milling = (wt. of bran/wt. of brown rice) ×100.

Satake milling meter measurement

Degree of milling (DOM) of all samples, including the brown rice was measured using a Satake milling meter (MM1B, Satake Japan). Prior to 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 (SDOM). 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 SDOM was calculated using both the whiteness and the transparency by a factory installed algorithm in the microcomputer of the milling meter. SDOM is displayed as a value from 0 to 199, where a value of 0 represents a SDOM level corresponding to brown rice and 199 represents a SDOM level of snow-white fully milled rice. Thus, larger the SDOM number, thorough or complete is the extent of bran removal (Chen and Siebenmorgan, 1997; Mohapatra and Bal, 2007). Five measurements were taken for each sample.

Hunter lab colour measurement

The colour values of the rice samples after polishing was also determined using Hunter Lab Colouri meter (D25, DP-9000, USA). The instrument consisted of a D-25 optical sensor (I-type) and a processor (DP-9000), which processed, displayed and printed the results of the measurements. The instrument was first calibrated using standard white tile provided by the manufacturer (L=91.10, a= -0.64, b= -0.43) as per the procedure given in the reference material. Hunter L [black (0)/white (100)], a [red (+)/green (-)] and b [yellow (+)/blue (-)] colour scale was selected for all measurements. Milled rice samples were kept on the specimen port (95 mm diameter) so as to cover the full exposed area of the window (port) to the light with the sample. This was achieved by placing the rice samples (150 g) milled to various degrees, in a glass bowl provided by the manufacturer. The bowl was covered by a light proof covering. Five measurements were made on each sample, after shaking the sample gently, and the average values of L, a, b were noted. The amount of variation, if any in the sample, was taken into account by shaking the samples every time the measurement was done, so that the effect of void space and orientation of the grains was nullified.

All the statistical analysis was made with Microsoft excel 2007 version. The polynomial fit equations were represented as Ax^2+Bx+C where, A, B, C are coefficients.

Results and Discussions

Relationship between degree of milling and polishing time

The polishing kinetics of 3 different varieties of rice is presented in Fig 1. As the polishing time increased the degree of milling increased. As it can be observed, the initial slope of the curve was higher, which remained almost constant afterwards. This indicated higher and uniform hardness in the core as compared to the outer layers. The same has been established by Mohapatra and Bal (2004). Higher bran removal during the initial phase of polishing indicated that germ was also removed within first 30 seconds of milling, after which the bran removal remained almost constant and after a 150 seconds, the degree of milling stabilized. A second order polynomial function was used to relate milling time with degree of milling in the experimental range, coefficients of which are tabulated in Table 1.

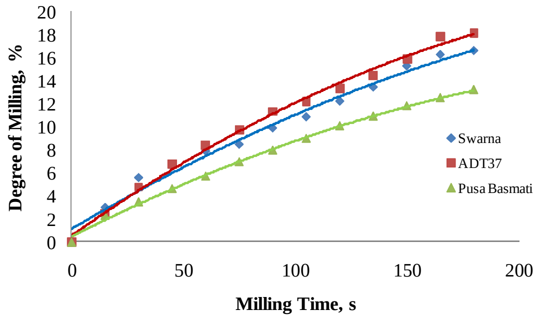


Fig 1: The relationship between milling time and degree of milling of 3 varieties of *indica* rice polished in a laboratory abrasive polisher

Relationship between Satake transparency and degree of milling

The relationship between Satake milling meter transparency values and degree of milling for 3 varieties of rice were presented in Fig 2. Initially the transparency value of the yellowish coloured Pusa Basmati was higher compared to ADT37 and Swarna. It could be reasoned out that Pusa Basmati had lighter bran covering its endosperm while, Swarna had relatively darker pigmented bran covering the endosperm. Pusa Basmati had thin layer bran on its surface thus requiring lesser degree of milling compared to the other two varieties. The transparency values tend to increase to certain extent, and then the values did not change much. This trend indicated that there was thorough removal of bran layer from the kernel surface, exposing only the starchy endosperm. On further milling, since starch property did not change, the optical values too did not change. It is always difficult to remove the bran streaks from the groves and ventral side of slender grain like Pusa Basmati, as the surface was less exposed to the emery surface. Therefore, even after 10 % of milling, the bran streaks remained on the ventral side of the kernel that would have affected the transparency values. There was a marked difference in the transparency values of brown rice and well milled rice for Swarna and ADT37. The transparency value of Swarna variety of rice was very prominent, as it got a shinier look after a higher degree of milling, even in abrasion milling. Since, ADT 37 was a mixture of white and red pigmented rice; its transparency values were lesser than the other two varieties. The transparency values did not vary statistically at 1 % level of significance among the cultivars (p=0.1967). The change in degree of milling brought about highly significant change ($p=5.5.59\times10^{-13}$) in the transparency values. The transparency values were related to degree of milling through a second order polynomial function.

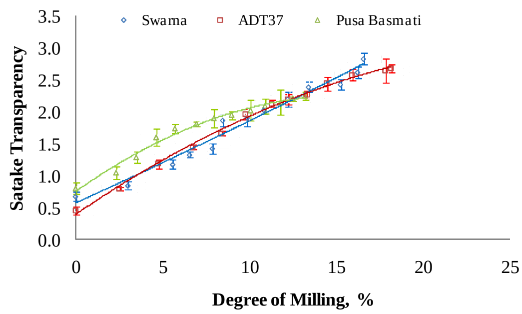


Fig 2: The relationship between degree of milling and Satake transparency of 3 varieties of *indica* rice polished in a laboratory abrasive polisher

The coefficients of polynomial fit between transparency and degree of milling is presented in Table 1.

Relationship between Stake whiteness and Degree of Milling

The whiteness value of Pusa Basmati was the highest in the brown rice stage (Fig 3), followed by Swarna and ADT37 (22.4>20.6>12.5). At 8 % bran removal the Satake whiteness values for Pusa Basmati, Swarna and ADT37 were 37, 33.6 and 28.0. This trend can be explained by the fact that ADT37 was a mixture of white and red grains and the optical values were influenced by the bran colour but on further milling the

Table 1: Coefficients of equations generated between colour values and degree of milling (DOM) for 3 varieties of *indica* rice

	Swarna				ADT 37				Pusa Basmati			
	A	B	C	R^2	A	B	C	R^2	A	B	C	R^2
DOM vs. milling time	-0.0002	0.1152	1.1198	0.9856	-0.0002	0.138	0.5282	0.9948	-0.0002	0.0987	0.4542	0.9977
DOM vs. Transparency	0.0005	0.1236	0.5748	0.9726	-0.0032	0.1855	0.3959	0.9961	-0.0061	0.192	0.7531	0.9837
DOM vs. Whiteness	-0.0019	1.555	19.131	0.9751	-0.0331	2.4729	10.589	0.9855	-0.0282	2.1178	21.682	0.9936
DOM vs. L value	-0.0176	1.414	50.225	0.9828	-0.0508	2.5078	39.755	0.9898	-0.0444	1.8997	52.117	0.9919
DOM vs. a value	0.0021	-0.267	3.0785	0.9431	-0.0157	-0.041	5.897	0.914	0.0107	-0.456	3.2627	0.9981
DOM vs. b value	0.0011	-0.135	16.148	0.9534	-0.0077	0.2000	12.252	0.9291	0.0109	-0.330	16.731	0.9784

whiteness value was found to have increased. As the milling progressed the starchy endosperm was exposed resulting in higher whiteness value, which then remained almost constant. However, the effect of cultivars and over all degree of milling on whiteness value was found to be highly significant ($p<0.0001$). The coefficients of the second degree polynomial equation generated for the aforementioned varieties were listed in Table 1.

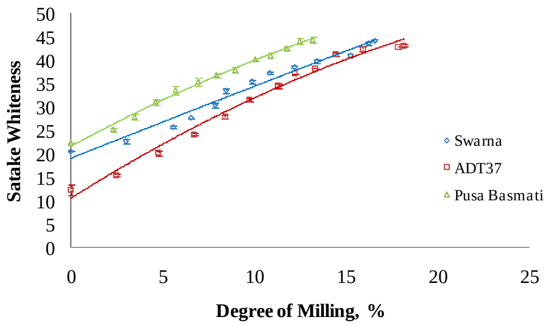
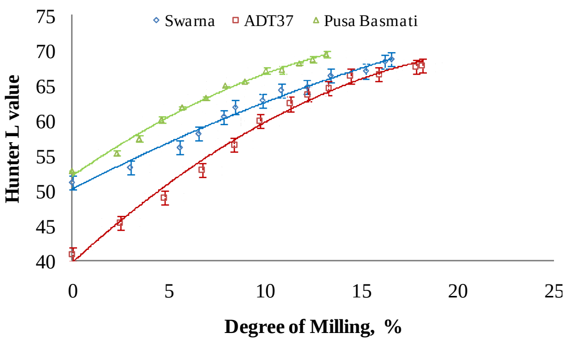


Fig 3: The relationship between degree of milling and Satake Whiteness of 3 varieties of *indica* rice polished in a laboratory abrasive polisher

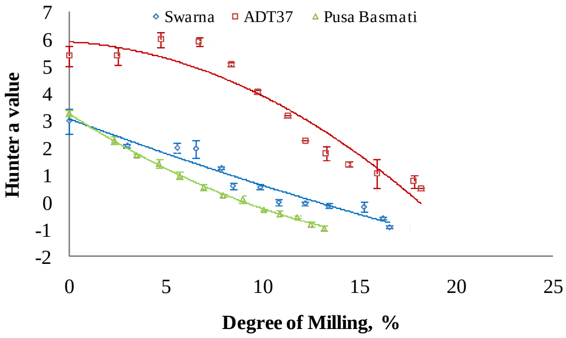
Relationship between Hunter Lab values and degree of milling

The relationship between the degree of milling and the hunter Lab values were presented in Fig 4 (i, ii, iii) for the 3 varieties considered in the investigation. It was found that the L-values increased from 51.22 to 68.74, 41.01 to 67.87 and 52.88 to 69.5 for Swarna, ADT 37 and Pusa Basmati, respectively. This indicated, with removal of bran the endosperm was exposed and the brightness value was more or less similar for all *indica* rice. The a-value decreased from 2.99 to -0.9, 5.38 to 0.49 and 3.28 to -0.95 for Swarna, ADT 37 and Pusa Basmati, respectively. Even after 16% bran removal, the positive a -value of ADT 37 rice indicated redness in the sample, which was influenced by the red pigment in the bran, whereas, the a-values were negative implying the greenness in Swarna and Pusa Basmati rice. The b-value decreased 16.18 to 14.01 and 16.99 to 14.22. Swarna and Pusa Basmati, respectively, however the values increased from 12.26 to 13.26 for ADT 37. The decrease in the yellowness in Swarna and Pusa Basmati with progressive milling implied that bran has more pigments than the endosperm. This finding corroborates the finding of Lamberts *et al*. (2007). The trend for ADT 37 however, was different than the other two varieties. The colour values indicated an increase in the yellowness value from the initial values. This could be attributed to the red pigments present in the outer layer, affecting the colour values, which when removed improved the appearance and the yellowness. Both degree of milling and verity affected the L ($p<0.003$), a ($p<0.0001$), b ($p<0.0001$), significantly at 95% confidence interval.

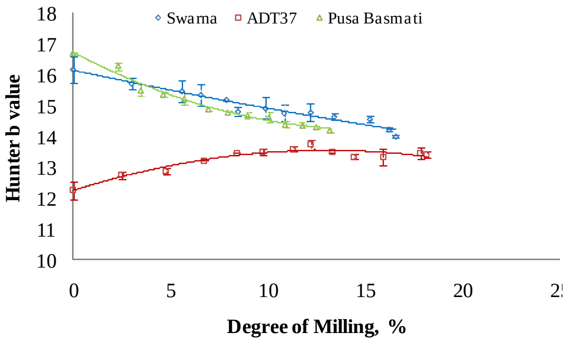
Colour of the rice depends upon many factors such as presence of white belly, thickness of bran layer, colour of the bran, chemical composition of kernel, and longitudinal creases on the kernel. Since rice caryopsis has an undulating surface with ridges and furrows, it is difficult to mill the rice grain uniformly. In removing the pigmented bran from the furrows, substantial endospermic material is also removed. This problem is specially encountered with variety like ADT37, which mixture of red and white grains. Hence to get a uniform colour values, the white grain had to be over-milled along with the red grains. In doing so, a lot of endospermic material was lost along with the bran. It was observed that the surface was uniformly white -



4(i)



4(ii)



4(iii)

Fig 4: Relationship between Hunter L (i), a (ii) and b (iii) values with degree of milling

when the rice samples were milled between 12 to 16 % for the three varieties tested. The optimum degree of milling based on colour, texture and specific energy consumption was suggested to be between 10-11% (Mohapatra and Bal, 2007) for the varieties tested. For red coloured grains high level of milling was needed in order to have complete removal of colour. Second degree polynomial equation was fitted to all the hunter Lab colour values with respect to degree of milling, coefficients being tabulated in Table 1.

Relationship between Satake degree of milling (SDOM) and Hunter L value

The Satake degree of milling is derived from the transparency and whiteness values by the factory installed program. The relationship between SDOM and Hunter L value is shown in Fig 5. A linear relationship existed between SDOM and Hunter L value for all the varieties considered in this investigation. The initial Satake DOM values for ADT 37 were zero. The red pigments influenced the SDOM values of ADT 37 till most of the red pigment containing bran layers are partly removed, exposing the white endosperm underneath. On further milling, there were no significant differences in the aforesaid values, as measured with the milling meter. This indicated thorough removal of bran layer and uniformity of colour of the endosperm. The results here revealed similar trends as reported by Siebenmorgen and Sun (1994), Chen and Siebenmorgan (1997) and Mohapatra and Bal (2007).

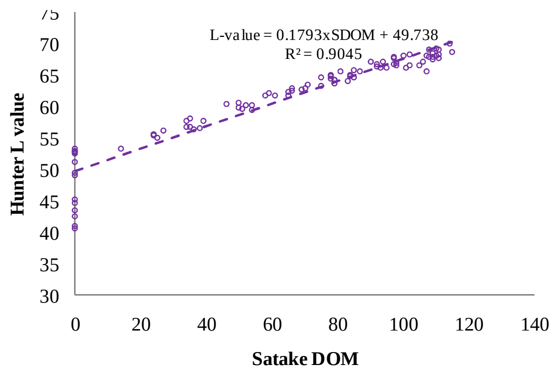


Fig 5: Relationship between Satake DOM and Hunter L values of *indica* rice milled to different degrees

Conclusions

It can be concluded that most pigments lie in the bran layer, therefore, with progressive milling as bran is removed, the transparency, whiteness increases, at the same time the redness and yellowness of the grains decreases, except for red pigmented grains, where yellowness improves with respect to the initial values, as the starchy endosperm is exposed. The L, a, b value of *indica* rice vary with cultivars. The light coloured grains like Pusa basmati need not be polished beyond 10%, which is inclusive of germ. Varieties like ADT 37, which have mixed white and red pigmented kernels, may be polished beyond 12% to get an appealing appearance; however, the bran so obtained can have nutraceutical applications, as they are considered to be rich in nutrients. There could be a linear relationship between hunter L-value and Satake degree of milling values, which can be alternately used for determining degree of milling.

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