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Research Article

A Study on the Effect of Degree of Milling (DOM) On Color and Physicochemical Properties of Different Rice Cultivars Grown in Punjab

Shruti Puri, Bhavnita Dhillon*, and Navdeep Singh Sodhi

Guru Nanak Dev University,
Amritsar-143005, Punjab, India.
* Corresponding Author: E-mail: bhavnita.dhillon@msn.com
Phone: +91-9465865000

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ABSTRACT:
Rice samples obtained from five different cultivars grown in Punjab were milled at varying degrees upto 10 % and were analyzed for their color and physicochemical properties. The varieties selected were PUSA, Somti, Sarbati, Golden Sella and PR-11. For the unmilled rice of all the varieties, moisture content was found highest in Sarbati (12.87%), ash content was highest in PR-11 (1.45%), crude fiber was highest in Sarbati (2.58%), protein (8.51%), fat content (1.72%) and carbohydrate content (81.02%) were highest in Golden Sella. Similarly, of all varieties L:B ratio (4.268) and thousand kernel weight (21.76 g) were highest in Golden Sella but bulk density was highest in Somti (0.822 g/ml). With increasing DOM, significant decrease in protein (20-25%), ash (58-72%), fat content (50-66%) and fiber (57-75%) was observed whereas moisture content showed little variations for all varieties. Similarly, there was increase in L:B ratio but decrease in thousand kernel weight and bulk density by 11-16%, 6-10% and 2-6%, respectively. Pearson correlation were established between various physical and color parameters at varying DOM for different varieties. It showed a positive significant correlation with L* and negative with a*. The overall color change followed the decreasing order from Somti, Golden Sella, PR-11, PUSA to Sarbati. Also, negative significant correlation was found between L:B ratio with 1000 kernel weight as well as bulk density for all varieties. Amylose content of the kernels showed significant correlation with physical properties as well as overall color change in the kernels.

Keywords: Rice, degree of milling (DOM), color, amylose, physical properties, physicochemical studies

[I] INTRODUCTION

Rice (*Oryzae sativa* L.) is an imperative grain feeding half of the world's population and generally consumed as a whole grain. In India, rice is grown in various regions due to which there comes significant difference in its composition and cooking quality. Main factors responsible for such variations are genetic and environmental [1]. Punjab is a major contributor of rice and adoption of high yielding varieties with matching technologies made it "Rice Bowl" of India. More than 60% of total cultivated land of rice in Punjab is in *kharif* season [2]. Milling of rice is a process involving various unit operations which convert paddy into well milled rice generally known as white rice [3]. Color of the kernel and head rice yield are two of the important parameters to study quality of milled rice. Various processes involved to obtain milled or polished rice are energy intensive, which reduces rice's nutritive value and increases its market value [4]. Being an agricultural produce, the market value of rice also depends upon the physical qualities after harvesting and whole grain (head rice) percentage is an essential criteria for rice processing industry [5].

Brown rice is considered more nutritious than white rice as it contains many biofunctional components such as fiber, vitamins, phytic acids and gamma amino butyric acid [6]. These components mainly exist in germ and bran layers which are removed during the milling process. In spite of the fact that brown rice is more nutritious, they have lower degree of acceptance due to its dark appearance, hard texture and greater cooking time [7]. But, now as the health consciousness is increasing day by day, brown rice consumption is being encouraged and more studies have been conducted in recent years [8, 9, 10] but still the trend is towards white rice consumption. The quality analysis of rice involves physicochemical determinations on the basis of composition, cooking properties or physical properties of cooked rice [11]. The knowledge and analysis of physical properties serve as an important factor during grains harvesting, transportation, storage, processing as well as manufacture and operation of various equipments used in processing. The commonly considered factors for learning drying and storage space of agricultural produce are: moisture level, specific volume, specific gravity and porosity [12].

As the consumer preferences varies from region to region, the amount of bran being removed or Degree of Milling (DOM) also varies. Difference between various aromatic and non aromatic varieties cannot be based only on aroma but also on variations in quantities of physicochemical properties in rice grains. The physicochemical properties in the rice grains are greatly influenced by degree of milling [8]. The present study focused on studying the effect of DOM on physicochemical properties as well as color of different rice varieties of Punjab.

[II] MATERIAL AND METHODS

2.1. Sample preparation

Paddy samples of five different varieties of rice namely PUSA, Somti, Sarbati, Golden Sella and PR-11 were obtained from a local company 'LalQuila' (Amar Singh Chawal Wala Private Limited, Amritsar, Punjab, India). LalQuila is a renowned Indian brand and an exporter of basmati varieties all over the world. The paddy samples were dehusked using sample sheller (KI370, Khera Instruments, Delhi, India). The samples were then polished upto 10% level of DOM using polisher (McGill Rice Miller No. 2, Rapsco, Brookshire TX, USA). The brown rice was considered as the rice obtained without milling and rest degrees i.e. 2, 4, 6, 8 and 10% were calculated by measuring the weight of rice before and after polishing. Broken kernels were removed by hand picking and polished rice samples were stored at -18 °C till further analysis.

2.2. Physicochemical studies

The composition of all the samples was determined using standard methods of [13]. Moisture content was determined by drying the sample in a hot air oven at 105°C till a constant weight was observed. Fat content was estimated by solvent extraction method (petroleum ether) using soxhlet apparatus. Ash content was calculated after sample incineration and then putting it in muffle furnace at 550°C. Crude fiber was also determined by digesting the sample with acid and alkali using crude fiber extraction apparatus. Crude protein was determined by micro-Kjeldhal method using Nitrogen to protein conversion factor as 5.95. Carbohydrate content of all the samples was determined by difference method.

2.3. Color characteristics

Various color parameters (L*, a*, b*, dE*) were determined using Ultra-Scan VIS Hunter Lab colorimeter (Hunter Associates Laboratory Inc, Reston, VA, U.S.A) on CIE color scale. Prior to color measurement, the instrument was calibrated using standard white and black tile. Then, the parameters were observed and reported as L*, a*, b*, dE*. The L* value indicates lightness from black (0) to white (100), a* value shows degree of red-green color, with higher a* value indicating more redness. The b* value shows degree of yellow – blue color, with higher b* indicating more yellowness. The dE* indicates the overall change in color of the samples and is calculated using equation 1 where L^*_0, a^*_0 and b^*_0 refer to the CIE values of unmilled rice of each variety.

$$dE^* = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2}$$

Equation 1

2.4. Physical properties

Thousand (1000) kernel weight, length–breadth ratio (L:B) and bulk density From all the samples, one thousand kernels were randomly selected and weighed separately. For calculating L:B ratio, rice kernels (n=10) were aligned length-wise and then the same kernels were aligned breadth-wise. The measurements were taken in mm using digital vernier caliper. Length to breadth ratio was recorded by dividing kernels length by their breadth. Bulk density was measured by taking the weight of known volume of the sample. Kernels were put into a graduated cylinder and tapped ten times and filled to 250ml. Results are then reported as g/ml [14, 1].

2.5. Amylose Content

Rice samples for its amylose content were determined by Iodine binding method given by [15]. Rice flour (100mg), ethanol 95% (1ml) and 1N NaOH (9ml) were added in volumetric flask of 100ml capacity and mixed thoroughly. Samples were then heated in boiling water bath for 10 min for starch gelatinization and are then allowed to cool to room temperature. Volume of the samples was made to 100ml and then aliquots (5ml) were transferred to another volumetric flask (100ml). To these flasks, 1N acetic acid (1ml) and Iodine solution (2ml) were added and volume was again made to 100ml. All contents were mixed and were allowed to stand for 20 min for color development. The absorbance was calculated at 620nm using visible spectrophotometer. The amylose content was determined and reported in percentage by comparing it with a standard curve prepared by using potato amylose.

2.6. Statistical Analysis

The statistical differences between the various properties as affected by varying DOM were tested by one way analysis of variance (ANOVA) and Duncan's Multiple Range test using SAS statistical software (Version 9.1.3.). The significance was measured at $P \leq 0.05$. The Pearson correlation coefficients for the relationship between different properties were calculated using SAS statistical software (Version 9.1.3.).

[III] RESULTS AND DISCUSSION

3.1. Compositional Studies

The chemical composition of various varieties namely PUSA, Somti, Sarbati, Golden Sella and PR-11 was analyzed for DOM varying from 0 to 10 % [Table I]. Of all the unmilled varieties, moisture content was found highest in Sarbati (12.87%) and least in Golden Sella (11.02%), protein was highest in Golden Sella (8.51%) and least in PR-11 (6.90%), ash content was highest in PR-11 (1.45%) and least in Sarbati (0.92%), fat content was highest in Golden Sella (1.72%) and least in PR-11 (1.34%), crude fiber was highest in Sarbati (2.58%) and least in Golden Sella (1.94%), carbohydrate content was highest in Golden Sella (81.02%) and least in Somti (80.05%). For all the varieties it was observed that with increase in degree of milling from 0-10%, the protein, ash, fat content and crude fiber content decreased significantly in the range of 20-25%, 58-72%, 50-66%and 57-75%, respectively. But, in moisture content no significant variations was observed.

The decrease in the compositional factors may be attributed to the fact that with increasing milling, more bran and germ was removed which is rich source of lipids, fiber and minerals. But the carbohydrate content increased significantly with increasing DOM. This showed that brown rice of all varieties had more nutritive value than the milled rice. With increasing milling, the nutritional quality of the grains is decreased. Similar influence of DOM on chemical composition of Jasmine rice has been studied by [10]. The study concluded that there is a significant decrease in the composition of rice grain with increasing DOM (0-10.9%). The study showed that there was a significant decrease in protein, ash, fat and crude fiber from 8.87-6.87%, 1.42-0.36%, 2.92-0.63% and 1.12-0.35%, respectively. A study by [16] also reported that protein content and minerals decreased when subjected to DOM (0-15%). The studies indicate that protein and mineral concentration decreases from the outer layers towards endosperm. But the level of total starch increases as the milling levels increased from surface to endosperm. With the increase in DOM (0-15%), protein content decreased from 9.2% to 6.569% and mineral content decreased from 1.6% to 1.35% but the carbohydrate content increased from 76.4% to 83.42%. In another study on surface lipid content of seventeen rough rice varieties, it was found that the content decreases when milled at DOM (0-40 s). The study showed a linear decrease in surface lipid content and the head rice yield of different cultivars with increase in DOM [17].

[Table I]

Variety	*% DOM*	*Moisture*	*Protein*	*Ash*	*Fat*	*Crude fiber*	*Carbohydrate*
PUSA	0	**11.56 ± 0.06**^{a}	**7.30 ± 0.02**^{a}	**1.04 ± 0.05**^{a}	**1.52 ± 0.04**^{a}	**2.09 ± 0.03**^{a}	75.43 ± 0.10^{f}
	2	11.48 ± 0.03^{b}	7.07 ± 0.03^{b}	0.93 ± 0.03^{b}	1.35 ± 0.02^{b}	1.86 ± 0.01^{b}	77.30 ± 0.09^{e}
	4	11.45 ± 0.02^{b}	6.93 ± 0.02^{c}	0.86 ± 0.02^{c}	1.18 ± 0.02^{c}	1.69 ± 0.03^{c}	77.88 ± 0.03^{d}
	6	11.50 ± 0.02^{ab}	6.33 ± 0.02^{d}	0.65 ± 0.02^{d}	1.03 ± 0.02^{d}	1.52 ± 0.02^{d}	78.99 ± 0.07^{c}
	8	11.48 ± 0.03^{b}	6.01 ± 0.03^{e}	0.56 ± 0.03^{e}	0.85 ± 0.03^{e}	1.21 ± 0.02^{e}	79.91 ± 0.03^{b}
	10	11.45 ± 0.01^{b}	5.74 ± 0.03^{f}	0.42 ± 0.02^{f}	0.76 ± 0.01^{f}	0.89 ± 0.03^{f}	**80.74 ± 0.03**^{a}
SOMTI	0	**11.83 ± 0.06**^{a}	**7.62 ± 0.07**^{a}	**1.22 ± 0.02**^{a}	**1.42 ± 0.02**^{a}	**2.36 ± 0.03**^{a}	75.56 ± 0.20^{f}
	2	11.83 ± 0.01^{a}	7.17 ± 0.02^{b}	1.10 ± 0.03^{b}	1.22 ± 0.02^{b}	1.99 ± 0.02^{b}	76.69 ± 0.03^{e}
	4	11.74 ± 0.02^{b}	7.03 ± 0.02^{c}	0.90 ± 0.02^{c}	1.01 ± 0.02^{c}	1.66 ± 0.05^{c}	77.65 ± 0.06^{d}
	6	11.78 ± 0.01^{ab}	6.90 ± 0.03^{d}	0.68 ± 0.02^{d}	0.87 ± 0.01^{d}	1.15 ± 0.03^{d}	78.62 ± 0.03^{e}
	8	11.81 ± 0.02^{a}	6.47 ± 0.01^{e}	0.54 ± 0.01^{e}	0.74 ± 0.02^{e}	0.92 ± 0.05^{e}	79.51 ± 0.02^{b}
	10	11.78 ± 0.03^{ab}	6.07 ± 0.04^{f}	0.34 ± 0.02^{f}	0.60 ± 0.01^{f}	0.69 ± 0.04^{f}	**80.50 ± 0.02**^{a}
G. SELLA	0	**11.02 ± 0.04**^{a}	**8.51 ± 0.04**^{a}	**1.32 ± 0.03**^{a}	**1.72 ± 0.03**^{a}	**1.94 ± 0.04**^{a}	75.48 ± 0.06^{f}
	2	11.02 ± 0.01^{a}	8.12 ± 0.05^{b}	1.10 ± 0.03^{b}	1.51 ± 0.02^{b}	1.75 ± 0.04^{b}	76.49 ± 0.10^{e}
	4	10.98 ± 0.01^{bc}	7.93 ± 0.02^{c}	0.86 ± 0.03^{c}	1.19 ± 0.02^{c}	1.49 ± 0.02^{c}	77.55 ± 0.08^{d}
	6	10.95 ± 0.01^{bc}	7.37 ± 0.03^{d}	0.74 ± 0.02^{d}	0.98 ± 0.03^{d}	1.12 ± 0.07^{d}	78.84 ± 0.07^{c}
	8	10.93 ± 0.01^{c}	6.94 ± 0.03^{e}	0.57 ± 0.03^{e}	0.75 ± 0.02^{e}	0.75 ± 0.04^{e}	80.06 ± 0.05^{b}
	10	10.98 ± 0.02^{ab}	6.55 ± 0.01^{f}	0.39 ± 0.01^{f}	0.58 ± 0.02^{f}	0.47 ± 0.01^{f}	**81.02 ± 0.03**^{a}
SARBATI	0	**12.87 ± 0.04**^{bc}	**7.92 ± 0.06**^{a}	**0.92 ± 0.01**^{a}	**1.42 ± 0.04**^{a}	**2.58 ± 0.03**^{a}	74.79 ± 0.03^{f}
	2	12.45 ± 0.01^{a}	7.25 ± 0.04^{b}	0.81 ± 0.01^{b}	1.21 ± 0.01^{b}	2.27 ± 0.02^{b}	76.03 ± 0.03^{e}
	4	12.34 ± 0.04^{c}	6.96 ± 0.04^{c}	0.69 ± 0.02^{c}	1.07 ± 0.04^{c}	1.92 ± 0.03^{c}	77.03 ± 0.14^{d}
	6	12.41 ± 0.02^{ab}	6.64 ± 0.02^{d}	0.54 ± 0.02^{d}	0.86 ± 0.03^{d}	1.56 ± 0.01^{d}	77.98 ± 0.03^{c}
	8	12.39 ± 0.04^{abc}	6.16 ± 0.04^{e}	0.46 ± 0.01^{e}	0.68 ± 0.04^{e}	1.05 ± 0.04^{e}	79.27 ± 0.06^{b}
	10	12.33 ± 0.01^{c}	5.96 ± 0.03^{f}	0.35 ± 0.01^{f}	0.57 ± 0.03^{f}	0.75 ± 0.02^{f}	**80.05 ± 0.03**^{a}
PR-11	0	11.95 ± 0.03^{a}	**6.90 ± 0.02**^{a}	**1.45 ± 0.02**^{a}	**1.34 ± 0.02**^{a}	**2.14 ± 0.02**^{a}	76.22 ± 0.01^{f}
	2	11.96 ± 0.02^{a}	6.69 ± 0.02^{b}	1.24 ± 0.04^{b}	1.10 ± 0.03^{b}	1.99 ± 0.02^{b}	77.03 ± 0.05^{e}
	4	11.93 ± 0.02^{a}	6.17 ± 0.04^{c}	1.04 ± 0.02^{c}	1.01 ± 0.02^{c}	1.75 ± 0.03^{c}	78.10 ± 0.02^{d}
	6	11.96 ± 0.02^{a}	6.02 ± 0.01^{d}	0.92 ± 0.02^{d}	0.79 ± 0.02^{d}	1.32 ± 0.05^{d}	78.99 ± 0.05^{c}
	8	11.95 ± 0.02^{a}	5.89 ± 0.02^{e}	0.77 ± 0.02^{e}	0.67 ± 0.02^{e}	0.99 ± 0.02^{e}	79.72 ± 0.10^{b}
	10	**11.97 ± 0.01**^{a}	5.50 ± 0.03^{f}	0.60 ± 0.02^{f}	0.58 ± 0.02^{f}	0.64 ± 0.02^{f}	**80.71 ± 0.02**^{a}

* All data is taken in triplicates

*One way ANOVA was done to evaluate the effect of DOM on physicochemical properties per variety

* Means followed by same letter in a column are not significantly different at $P<0.05$

Table I: Physicochemical properties of various varieties with varying DOM

3.2. Study of Physical Parameters

Physical parameters are important in order to study harvesting, transport, manufacture and operation of various equipments related to grain processing, etc. [12]. The knowledge of these properties also helps in evaluating important facts to determine their appropriate usage. In unmilled rice of all varieties, L:B ratio was highest in Golden Sella (4.268) and least in Sarbati (4.021), thousand kernel weight was highest in Golden Sella (21.76 g) and least in Sarbati (15.90 g), bulk density was highest in Somti (0.822 g/ml) and least in PUSA (0.776 g/ml) [Table II]. For all the varieties it was observed that with increase in DOM from 0-10 % there was increase in L:B ratio but decrease in thousand kernel weight and bulk density by 11-16%, 6-10% and 2-6%, respectively.

[Table II]

Variety	*% DOM*	**L : B**	**1000 kernel weight (gm)**	**Bulk Density (g/ml)**	***L****	***a****	***b****
PUSA	0	4.144 ± 0.04^{d}	**16.76 ± 0.008^{a}**	**0.776 ± 0.01^{a}**	62.73 ± 0.65^{c}	**3.46 ± 0.21^{a}**	**17.50 ± 0.22^{a}**
	2	4.208 ± 0.03^{cd}	16.60 ± 0.006^{b}	0.761 ± 0.01^{ab}	62.28 ± 0.49^{c}	3.43 ± 0.17^{a}	17.10 ± 0.40^{ab}
	4	4.277 ± 0.02^{c}	16.35 ± 0.006^{c}	0.759 ± 0.01^{ab}	63.32 ± 1.52^{c}	2.99 ± 0.22^{b}	16.99 ± 0.21^{b}
	6	4.292 ± 0.12^{c}	16.15 ± 0.004^{d}	0.756 ± 0.02^{b}	65.31 ± 0.63^{b}	2.62 ± 0.11^{c}	16.97 ± 0.21^{b}
	8	4.517 ± 0.10^{b}	15.84 ± 0.007^{e}	0.752 ± 0.01^{b}	69.57 ± 1.19^{a}	1.63 ± 0.15^{d}	15.66 ± 0.23^{c}
	10	**4.810 ± 0.04^{a}**	15. 47 ± 0.014^{f}	0.744 ± 0.02^{b}	**71.22 ± 0.73^{a}**	0.88 ± 0.08^{e}	15.42 ± 0.21^{c}
SOMTI	0	4.208 ± 0.05^{e}	**21.51 ± 0.006^{a}**	**0.822 ± 0.015^{a}**	58.62 ± 0.82^{e}	**5.01 ± 0.23^{a}**	15.74 ± 0.42^{b}
	2	4.320 ± 0.07^{d}	21.10 ± 0.005^{b}	0.820 ± 0.009^{a}	63.61 ± 0.85^{d}	5.01 ± 0.24^{a}	17.28 ± 0.08^{a}
	4	4. 491 ± 0.07^{c}	20.04 ± 0.009^{c}	0.816 ± 0.012^{ab}	64.10 ± 0.43^{d}	5.08 ± 0.35^{a}	**17.76 ± 0.74^{a}**
	6	4.578 ± 0.07^{c}	19.48 ± 0.004^{d}	0.817 ± 0.012^{ab}	65.57 ± 0.78^{c}	4.43 ± 0.16^{b}	17.24 ± 0.17^{a}
	8	4.681 ± 0.07^{b}	19.96 ± 0.007^{e}	0.807 ± 0.009^{ab}	68.15 ± 0.49^{b}	3.28 ± 0.038^{c}	16.34 ± 0.27^{b}
	10	**4.901 ± 0.03^{a}**	19.94 ± 0.008^{f}	0.799 ± 0.019^{b}	**70.54 ± 1.22^{a}**	2.49 ± 0.26^{d}	15.97 ± 0.17^{b}
G. SELLA	0	4.268 ± 0.05^{d}	**21.76 ± 0.019^{a}**	**0.786 ± 0.014^{a}**	51.36 ± 1.69^{c}	**6.18 ± 0.58^{a}**	14.28 ± 0.66^{d}
	2	4.380 ± 0.04^{c}	21.37 ± 0.007^{b}	0.766 ± 0.013^{b}	51.99 ± 0.84^{c}	5.96 ± 0.17^{a}	15.65 ± 0.47^{c}
	4	4.362 ± 0.08^{c}	21.09 ± 0.008^{c}	0.756 ± 0.012^{bc}	51.91 ± 0.69^{c}	5.98 ± 0.19^{a}	15.81 ± 0.64^{c}
	6	4.383 ± 0.04^{c}	21.00 ± 0.006^{c}	0.751 ± 0.016^{bc}	52.09 ± 1.06^{c}	5.40 ± 0.06^{b}	15.82 ± 0.52^{c}
	8	4.511 ± 0.05^{b}	20.34 ± 0.009^{d}	0.742 ± 0.012^{c}	56.56 ± 0.70^{b}	4.88 ± 0.26^{c}	18.73 ± 0.22^{b}
	10	**4.772 ± 0.05^{a}**	20.31 ± 0.006^{d}	0.737 ± 0.016^{c}	**60.41 ± 0.89^{a}**	4.49 ± 0.01^{c}	**19.73 ± 0.55^{a}**
SARBATI	0	4.021 ± 0.055^{e}	**15.90 ± 0.021^{a}**	**0.786 ± 0.017^{a}**	63.79 ± 0.66^{c}	**3.30 ± 0.17^{a}**	**17.12 ± 0.25^{a}**
	2	4.107 ± 0.04^{d}	15.367 ± 0.009^{b}	0.772 ± 0.016^{ab}	65.31 ± 0.51^{b}	2.58 ± 0.07^{b}	16.83 ± 0.40^{a}
	4	4.238 ± 0.046^{c}	15.180 ± 0.01^{c}	0.759 ± 0.023^{bc}	65.46 ± 1.06^{b}	2.65 ± 0.48^{b}	16.01 ± 0.15^{b}
	6	4.335 ± 0.024^{b}	14.897 ± 0.007^{d}	0.758 ± 0.012^{bc}	65.78 ± 0.13^{b}	2.75 ± 0.12^{b}	16.12 ± 0.42^{b}
	8	4.371 ± 0.028^{b}	14.887 ± 0.005^{d}	0.741 ± 0.015^{c}	68.41 ± 1.34^{a}	1.92 ± 0.11^{c}	15.08 ± 0.34^{c}
	10	**4.540 ± 0.041^{a}**	14.847 ± 0.006^{e}	0.763 ± 0.008^{bc}	**69.39 ± 0.68^{a}**	1.96 ± 0.09^{c}	14.67 ± 0.30^{c}
PR-11	0	4.071 ± 0.04^{e}	**17.568 ± 0.007^{a}**	**0.779 ± 0.012^{a}**	65.68 ± 0.31^{f}	**3.82 ± 0.11^{a}**	**19.06 ± 0.25^{a}**
	2	4.126 ± 0.03^{d}	16.907 ± 0.009^{b}	0.777 ± 0.007^{a}	67.48 ± 0.22^{e}	3.12 ± 0.06^{b}	18.62 ± 0.09^{a}
	4	4.160 ± 0.03^{c}	16.085 ± 0.009^{c}	0.768 ± 0.009^{ab}	69.39 ± 0.75^{d}	2.62 ± 0.08^{c}	18.66 ± 0.18^{a}
	6	4.245 ± 0.02^{c}	15.960 ± 0.004^{d}	0.765 ± 0.019^{ab}	71.61 ± 0.16^{c}	1.67 ± 0.01^{d}	17.32 ± 0.13^{b}
	8	4.377 ± 0.03^{b}	15.866 ± 0.006^{e}	0.767 ± 0.007^{ab}	72.92 ± 0.58^{b}	1.18 ± 0.15^{e}	16.45 ± 0.31^{c}
	10	**4.564 ± 0.02^{a}**	15.690 ± 0.061^{f}	0.750 ± 0.017^{b}	**74.43 ± 0.37^{a}**	0.76 ± 0.19^{f}	15.93 ± 0.47^{d}

* Readings for L, a, b are taken in triplicates and rest are taken five times

* One way ANOVA was done to evaluate the effect of DOM on physical and color properties per variety

* Means followed by same letter in a column are not significantly different at $P<0.05$

Table II: Effect of DOM on Physical and Color parameters

Correlations between various physical parameters and DOM were established for all the varieties (Table III-VII). For all the varieties, L:B ratio showed a significant positive correlation from 0.906-0.985 with increasing DOM. This may be due to the fact that with increasing milling, the breadth of the kernels decreased because of the shearing action thus decreasing the breadth and increasing the L:B ratio. The thousand kernel weight and bulk density showed a negative correlation of 0.87-0.989 and 0.73-0.93, respectively for all varieties with degree of milling. This is because the weight of the kernels decreased with the removal of bran layers during milling. Also, the kernels become more slender in shape with increasing DOM and voids during packing increased thus decreasing the bulk density. For all varieties, L:B ratio showed a significant negative correlation with 1000 kernel weight and bulk density (Table III-VII). In a study, a correlation coefficient for milled rice from different rice cultivars between various physico-chemical parameters and cooking properties was established. It showed a negative correlation of 0.29 between L:B ratio and 1000 kernel weight [18]. In another study, twenty three milled rice varieties were evaluated for their physicochemical, textural and cooking properties. A correlation among various parameters of milled rice with different cultivars was developed. The results showed a negative correlation of r = -0.652 between L:B ratio and bulk density at P<0.01, concluding that brown rice had higher bulk density than white rice [1].

[Table III]

	DOM	*L:B*	*1000 ker. Wt.*	*bulk density*	*amylose*	*L**	*a**	*b**	*dE**
DOM	1.000								
L:B	0.928	1.000							
1000 ker. Wt.	-0.989	-0.941	1.000						
bulk density	-0.934	-0.891	0.897	1.000					
Amylose	0.976	0.876	-0.969	-0.852	1.000				
L*	0.920	0.879	-0.941	-0.805	0.963	1.000			
a*	-0.967	-0.925	0.976	0.846	-0.972	-0.974	1.000		
b*	-0.834	-0.833	0.915	0.791	-0.949	-0.899	0.940	1.000	
dE*	0.940	0.895	-0.952	-0.817	0.975	0.986	-0.981	-0.943	1.000

All values are significant at P<0.01

Table III: Pearson correlation for variety PUSA at varying DOM

[Table IV]

	DOM	*L:B*	*1000 ker. Wt.*	*bulk density*	*amylose*	*L**	*a**	*b**	*dE**
DOM	1.000								
L:B	0.981	1.000							
1000 ker. Wt.	-0.870	-0.903	1.000						
bulk density	-0.888	-0.819	0.560*	1.000					
Amylose	0.969	0.965	-0.900	-0.723	1.000				
L*	0.958	0.920	-0.822	-0.794	0.885	1.000			
a*	-0.942	-0.851	0.582*	0.845	-0.825	-0.857	1.000		
b*	-0.201	-0.103 NS	-0.258NS	0.301 NS	-0.107 NS	-0.009 NS	0.512*	1.000	
dE*	0.960	0.925	-0.820	-0.808	0.888	0.997	-0.866	-0.034	1.000

All values are significant at P<0.01, *Values significant at P<0.05 but not significant at P<0.01, NS: Not significant.

[Table V]

	DOM	*L:B*	*1000 ker. Wt.*	*bulk density*	*amylose*	*L**	*a**	*b**	*dE**
DOM	1.000								
L:B	0.985	1.000							
1000 ker. Wt.	-0.914	-0.886	1.000						
bulk density	-0.730	-0.682	0.833	1.000					
Amylose	0.964	0.975	-0.857	-0.630	1.000				
L*	0.928	0.886	-0.766	-0.545*	0.894	1.000			
a*	-0.834	-0.783	0.766	0.599	-0.819	-0.896	1.000		
b*	-0.935	-0.907	0.806	0.668	-0.910	-0.811	0.815	1.000	
dE*	0.925	0.901	-0.766	-0.539*	0.910	0.986	-0.892	-0.872	1.000

All values are significant at P<0.01, *Values significant at P<0.05 but not significant at P<0.01.

Table V: Pearson correlation for variety Sarbati at varying DOM

[Table VI]

	DOM	*L:B*	*1000 ker. Wt.*	*bulk density*	*amylose*	*L**	*a**	*b**	*dE**
DOM	1.000								
L:B	0.906	1.000							
1000 ker. Wt.	-0.976	-0.861	1.000						
bulk density	-0.798	-0.569*	0.763	1.000					
Amylose	0.965	0.943	-0.921	-0.652	1.000				
L*	0.918	0.922	-0.840	-0.446^{NS}	0.897	1.000			
a*	-0.963	-0.866	0.884	0.577	-0.929	-0.874	1.000		
b*	0.948	0.899	-0.939	-0.594	0.911	0.954	-0.857	1.000	
dE*	0.903	0.938	-0.854	-0.477*	0.919	0.988	-0.877	0.950	1.000

All values are significant at P<0.01, NS: Not significant, *Values significant at P<0.05 but not significant at P<0.01.

Table VI: Pearson correlation for variety Golden Sella at varying DOM

[Table VII]

	DOM	*L:B*	*1000 ker. Wt.*	*bulk density*	*Amylose*	*L**	*a**	*b**	*dE**
DOM	1.000								
L:B	0.947	1.000							
1000 ker. Wt.	-0.930	-0.805	1.000						
bulk density	-0.844	-0.912	0.698	1.000					
Amylose	0.958	0.843	-0.974	-0.761	1.000				
L*	0.996	0.921	-0.936	-0.830	0.963	1.000			
a*	-0.992	-0.919	0.928	0.826	-0.968	-0.991	1.000		
b*	-0.979	-0.926	0.800	0.863	-0.877	-0.940	0.962	1.000	
dE*	0.995	0.930	-0.922	-0.836	0.955	0.998	-0.994	-0.956	1.000

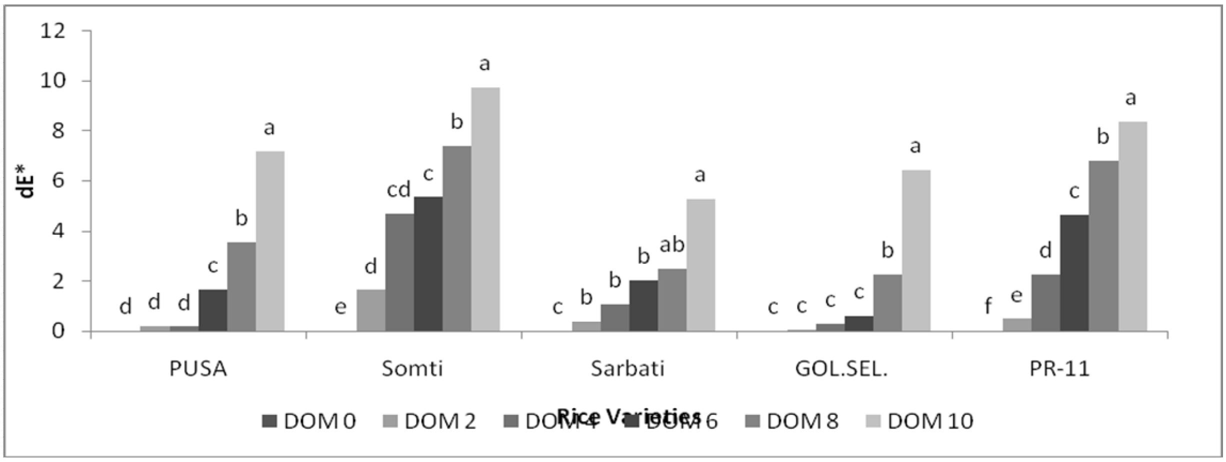
All values are significant at P<0.01

Table VII: Pearson correlation for variety PR-11 at varying DOM

3.3. Effect of DOM on color

As the amount of bran varies with different varieties and agronomic practices, the effect of bran removal on color of rice kernels with increasing DOM was observed. The degree of milling showed great influence on the overall color change of the kernels. With increasing degree of milling the color of the rice kernels became lighter (Figure I). The maximum change in color with increasing DOM was observed in variety Somti. The overall change followed the decreasing order from Somti, Golden Sella, PR-11, PUSA to Sarbati. Color change is defined by the parameters L*, a*, b*, dE*, where L* value indicates the lightness with a higher positive value showing lighter color, a* value depicts degree of red-green color, with a high a* value indicating redness. The b* value depicts the degree of yellow-blue color, with a higher positive b* showing more yellowness. Pearson correlation between various color parameters at varying DOM for different varieties was studied. The lightness (L*) and overall color change (dE*) had a significant ($P<0.01$) positive correlation with DOM for all the varieties i.e. 0.920 and 0.940, 0.958 and 0.960, 0.928 and 0.925, 0.918 and 0.903, 0.996 and 0.995 for varieties PUSA, Somti, Sarbati, Golden Sella and PR-11, respectively. The a* values have shown a significant ($P<0.01$) negative correlation with DOM for all varieties in the range of 0.834 to 0.992.Also, b* values showed significant ($P<0.01$) negative correlation with DOM for all varieties except Golden Sella which showed a significant positive correlation of 0.949 with DOM. This may be due to the fact that the kernels of Golden Sella variety were darker in appearance than the other varieties.

*All readings were taken in triplicates



*Values followed by the same letter in each variety are not significantly different ($P \leq 0.05$)

Figure I: Effect of varying DOM on overall color change for different varieties

There was less significant color change at lower degrees of milling in PUSA (DOM 0 to 4), Golden Sella (DOM 0 to 6) and Sarbati (DOM 2 to 6) (Figure I). This may be because some of the bran fractions still remained on the kernels after milling. In case of Golden Sella variety, minimum color change was observed may be because it is a parboiled variety and color of bran particles had already seeped into the inner layers of kernel which could not be removed in early millings. But all the varieties showed significant color change at higher milling degrees. Though, intensity of color of the rice kernels has a negative impact on consumer acceptance but it is an indication of the amount of bran present on the kernel. Effect of milling on color intensity has been studied for Japonica and Indica varieties by [19]. They showed that for Japonica and Indica varieties, at 10% DOM the lightness and color intensity was 71.6 and 12.8, and

69.3 and 15.5, respectively. In their study, lightness and color intensity was found to be dependent on the severity of milling operations which showed greater lightness value with higher DOM. In the present study, Pearson correlation was established between the color parameters and overall color change with physical parameters. It was observed that overall color change had a positive significant ($P<0.01$) correlation with the L:B ratio (0.895-0.938) and amylose content (0.888-0.975) for all varieties at varying DOM. But, it had negative significant ($P<0.01$) with 1000 kernel weight (0.766-0.952) for all varieties at varying DOM (Table III-VII). Similar trend was observed by [20] which showed that for various varieties kernel whiteness increased with the increasing DOM and a non linear relationship between milling and whiteness index was established. The study also found a positive significant correlation at $P\leq0.01$ between the amylose content and the whiteness index. Hence, it was concluded from the study that the whiteness could be estimated from the physicochemical properties of rice.

3.4. Effect of DOM on Amylose content

Amylose content is an important parameter in relation to the physical properties as well as color change. For all the varieties, an increasing trend was observed in amylose content with increasing milling levels. With increasing DOM, amylose content of all the varieties with increased by 0.5-3%.The change in amylose content followed the decreasing order PR-11, Somti, Golden Sella, Sarbati and PUSA. As reported earlier that with increasing DOM, carbohydrate content of the kernels increase which is supporting the fact that there is an increase in amylose content. Amylose content also showed a significant correlation with physical properties as well as overall color change in the kernels. It showed a positive significant correlation with L:B ratio, but negative significant correlation with 1000 kernel weight and bulk density for all the varieties. It also showed a positive significant correlation with the overall color change of the kernels. This may be due to the fact that with the increasing DOM, bran was removed and lightness of kernels increased. In a study, different Hom Mali rice varieties and rough rice varieties were subjected to varying degree of milling i.e. from 0-15%. All the varieties were evaluated for its apparent amylose content and it showed increase in its content with increasing DOM [8].

[IV] CONCLUSION

This study showed that there was significant decrease in the physicochemical properties of different varieties with varying DOM. This shows that the rice milled at lower level are more nutritious than white or completely milled rice. Hence, health consciousness and need to consume low milled rice should be created for better life as they are more nutritious. The physical parameters are important in order to determine the appearance, consumer acceptance, handling, storage and transportation. The increase in DOM showed a significant increase in L:B ratio, 1000 kernel weight, lightness of kernel and amylose content but bulk density of the kernels decreased. Rice milling industries will also benefit as the processing will be reduced and broken kernels will be minimized. More functional products can be made with suitable DOM level.

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