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Effect of grain moisture on milling characteristics of cold tolerant rice varieties of Kashmir valley

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ABSTRACT

Rice is regarded as an important cereal crop for majority of global population and it is developed by processing of paddy into white rice by milling. The milling of rice results in lowering down the quality attributes that are important for commercial success of a variety. The head rice yield (HRY) is an important criterion judging the acceptability of grains and its low values are not desired and ultimately results in lower consumer preference. The moisture content in paddy during its milling is an important factor determining HRY of varieties. The moisture content of Shalimar II and III paddy varieties was set to 10, 12 and 14 %. The grains were milled and observed for different milling and dimensional characteristics. The moisture content did not showed any significant effect on milling yield but HRY of paddy varieties depicted an evident difference with 14 % moisture content resulting in lower development of brokens and consequently higher HRY. The dimensions of Shalimar II and III reduced with milling and the decline in dimensions was more evident due to de-husking than due to polishing.

Keywords: Degree of milling, Head rice yield, Milling recovery, Shalimar II, Shalimar III

1. INTRODUCTION

Rice is an important agricultural cereal crop grown throughout world and is consumed by more than half of global population [1, 2]. The global production of rice is dominated by Asian subcontinent providing more than 90 % to overall paddy production. In India the production of rice in year 2010 was 144 MT that increased to 159 MT in 2016 and the annual production ranks second only after sugar cane [3]. More than half of world's population is dependent on rice due to staple food stature [4] and in Kashmir valley the rice is also staple food of local population [5]. The temperate climate of Kashmir valley limits grown of paddy to particular months and a slight variation in sowing season affects the crop yield as it requires plenty of sun shine and water with latter not a problem while former along with decrease in temperature acts as the main hurdle for its growth. The varieties grown in Kashmir are different with the rest grown in other parts as the crop has to face and survive cold climate with average temperatures always below 30 ^{o}C [6] and the varieties are developed by Rice Research Institute Khudwani. Cold tolerant rice varieties with short growth period are cultivated in the region with prominent ones include Jehlum, Kohsar, Chenab, Barakat, Shalimar I, II and III withan average yield of is 6 to 7 tons/ Ha.

The processing of paddy to white rice is associated with quality losses therefore proper understanding of processing is necessary to minimize the quality changes taking place during processing of paddy. Around 45 %

losses in milling were reported due to incompetent operators and poor functioning of equipment [7] and the amount of portion affected by milling process itself demands the need of subject importance. Processing of rice involves de-husking followed by its polishing as the two main operations of milling process. The removal of husk id achieved in first step while the second step is related to removal of thin layer bran thereby yielding a white rice kernel. The nutritive value of white rice is less than brown rice but still easy digestibility and color of grains are preferable criteria to consumers [8]. The milling process of rice is governed by different parameters viz. head rice yield (HRY) and milling recovery (MR). Milling recovery is total amount of white rice containing whole as well as broken grains whereas HRY gives the percentage of whole rice obtained after milling process. Rice grains that are 75 % or greater in length of its original grain are categorized as head rice and below 75 % of its length, grains are considered as brokens [9]. The successful rice varieties must provide higher yields of HRY and therefore it is regarded as an important criterion while developing new rice varieties by virtue of breeding programs [10]. The amount of bran removed while milling operation is provided by degree of milling (DOM) and bran as a source of nutritionally rich components provides information about nutritive value of different grains and is also an important indicator of economic return [11]. The low marketability of broken rice due to its cooking characteristics predict the success of a rice variety and varieties yielding higher HRY and low brokens tend to successful [12]. It has been reported that HRY and DOM are affected by milling time and grain thickness [13]. The grain dimensions are useful in developing sieve separators and for calculating different quantities like surface area, sphericity, aspect ratio, equivalent diameter and geometric mean diameter that are useful in predicting grain modelling in different operations including drying, cooling, aeration and heating [14]. The total milling outcome of paddy grains is predicted by thousand grain mass and any deviation from such values corresponds to milling loss due to grain breakage, presence of dockage and immature kernels [15,16].

The present study was carried out for two paddy varieties commonly grown in Kashmir region i.e., Shalimar II and Shalimar III. The varieties were studied for their milling characteristics and also effect of moisture on such characteristics was investigated. The grains were also observed for changes in dimensional properties taking place due to milling. The investigation can help in providing information to general public and aware people about the losses taking place during milling of grains.

2. MATERIALS AND METHODS

2.1 Materials

The two varieties of paddy namely Shalimar II and Shalimar III used in current study were procured from Rice Research Institute Khudwani, Kashmir. The grains were procured immediately after harvest and were analysed for moisture content in a hot air oven [17]. The oven was set to 105 ^{o}C and samples placed in pre-weighed petri-plates were placed in the oven for 24 hours determination of moisture content. The moisture content of rice kernels was around 22 %. The moisture content of paddy grains was brought to 10, 12 and 14 % by drying the grains in hot air oven set at a temperature of 40 ^{o}C. The paddy kernels were weighed occasionally and calculated for moisture content and were left for drying until desired moisture content of grains was reached.

2.2 Milling or paddy

The paddy grains of Shalimar II and Shalimar III with 10, 12 and 14 % moisture content were milled for obtaining white rice. The process of milling paddy grains is shown in Figure 1 and involves use of de-husker at first to remove its hull or outer covering thereby transforms paddy grains into brown rice. Around 100 g od paddy grains were used in each experiment for milling purpose and after passing it through de-husker yielded brown rice and husk. The white rice was obtained by using a polisher that removes the thin fat rich bran layer. The time for polishing was set for thirty seconds for each experimental run in order to maintain uniformity in results. The white milled rice contains a mixture of whole or head rice and brokens that were separated by using a laboratory rice grader. The brown and white rice in form of whole as well as brokens formed by respective operations were weighed on a weighing balance with an accuracy of ±0.001 g along with the paddy kernels.

2.3 Milling characteristics

Milling characteristics of paddy was determined in form of milling recovery (MR), head rice yield (HRY) and degree of milling (DOM) [8, 18]. The milling recovery (MR) of paddy was calculated from weight of milled rice and weight of initial paddy sample in form of following equation:

$$MR(\%) = \frac{W_m}{W_i} \times 100 \quad (1)$$

Head rice yield (HRY) consists of milled grains whose length is minimum ¾ or more of a grain whereas degree of milling (DOM) gives extent of bran removal and is calculated as:

$$HRY(\%) = \frac{W_h}{W_i} \times 100 \quad (2)$$

$$DOM(\%) = \frac{(W_b - W_m)}{W_i} \times 100 \quad (3)$$

Where, W_m is weight of milled rice containing both broken as well as head rice, W_i is weight of paddy used for milling, W_h is weight of head rice or whole rice and W_b is weight of brown rice.

2.4 Dimensional characteristics

The milling operation resulted in formation of brown and white rice that along with paddy grains were studied for their dimensional characteristics measured by a grain meter with a least count of 0.01 mm. The dimensions were recorded for rough rice, brown rice and white rice by taking a minimum of 10 grains randomly selected from each variety. The sphericity, equivalent diameter (ED), geometric mean diameter (GMD) and aspect ratio of grains was calculated by using following equations [19]:

$$GMD(mm) = (L \times W \times T)^{1/3} \quad (4)$$

$$ED\ (mm) = \frac{(L+W+T)}{3} \quad (5)$$

$$Sphericity\ (\%) = \frac{GMD}{L} \quad (6)$$

$$Aspect\ ratio = \frac{W}{L} \quad (7)$$

where, L is length, W is width, T is thickness, GMD is geometric mean diameter and ED is equivalent diameter.

2.6 Thousand kernel weight

Around 100 grains of sample were counted and weighed on an electronic weighing balance with a least count of 0.001 g. The recorded weight was multiplied with 10 to get 1000 kernel weight [20].

2.7 Analysis of data

All experiments were replicated three times and the necessary graphs of different milling characteristics were plotted by using Microsoft excel 2010. Statistica software was used for data analysis and Duncan's multiple range test was used for estimating significant differences.

3. RESULTS AND DISCUSSION

3.1 Milling process

The paddy grains conditioned to 10, 12 and 14 % moisture content were milled using a rice de-husker and polisher. The milling yields of Shalimar II and Shalimar III rice kernels in form of different products viz. white rice, brown rice and bran are shown in Table 1and the results are based on the fact of using an initial weight of 100 g of paddy grains for the process. The amount of husk in case of Shalimar II paddy grains was more regardless the different moisture conditioning of their grains. The amount of husk Shalimar III ranged from 20.92 to 21.27 g/100g for paddy grains of different moisture contents while in case of Shalimar II the yield of husk ranged from 22.05 to 22.14 g/100g. The moisture conditioning of paddy kernels didn't had any significant effect hulling process as shown by almost similar amount of husk in Shalimar II and III rice varieties. The amount of bran in Shalimar II ranged from 6.49 to 6.92 g/100g of paddy while in case of Shalimar III it ranged from 7.20 to 7.51 g/100g of paddy. The presence of bran was higher on Shalimar III paddy variety and moisture content of paddy had an evident effect on bran removal rate. The low moisture content comparatively hindered the process of bran removal due to strong bonds developed due to presence of low moisture in paddy grains.

Table 1 yield of different products obtained during milling of paddy varieties

Rice products (g/100g)	**Shalimar II**			**Shalimar III**		
	10%	**12%**	**14%**	**10%**	**12%**	**14%**
Brown rice	77.91 ± 0.89^a	77.86 ± 1.04^a	77.95 ± 0.85^a	78.92 ± 1.12^a	79.08 ± 1.16^a	78.73 ± 1.08^a
White rice	71.42 ± 0.62^a	71.22 ± 0.96^a	71.03 ± 0.97^a	71.72 ± 0.91^a	71.49 ± 0.82^a	71.23 ± 1.10^a
Husk	22.09 ± 0.54^a	22.14 ± 0.47^a	22.05 ± 0.56^a	21.08 ± 0.34^a	20.92 ± 0.38^a	21.27 ± 0.26^a
Bran	6.49 ± 0.23^a	6.64 ± 0.17^a	6.92 ± 0.22^a	7.20 ± 0.25^a	7.59 ± 0.27^a	7.50 ± 0.19^a

Values represent mean±standard deviation and values with different superscripts along a row for a particular individual variety represent a statistical difference.

3.2 Milling recovery

The amount of white rice kernels both whole and brokens comprise milling recovery of a paddy variety. Milling recovery of grains gives extent of milling process by providing the yield of white rice from paddy. The effect of

moisture content of paddy on milling recovery of Shalimar II and Shalimar III rice varieties are shown in Fig. 1. The milling recovery of Shalimar III is comparatively higher than Shalimar II at all conditioned moisture contents. Visualizing the results of milling recovery indicate lack of any apparent difference in its yield at different moisture contents. The milling recovery of Shalimar II with moisture content of 14 % was 71.72 % while the grains with moisture content of 10 and 12 % provided a milling yield of 71.42 and 71.22 %, respectively. Milling recovery in Shalimar III paddy containing moisture content of 10, 12 and 14 % was 71.71, 71.03 and 71.23 %, respectively. The decrease in HRY of paddy grains at lower moisture content during milling process was also observed by Ilieva et al. [21] and Nasirahmadi et al. [22].

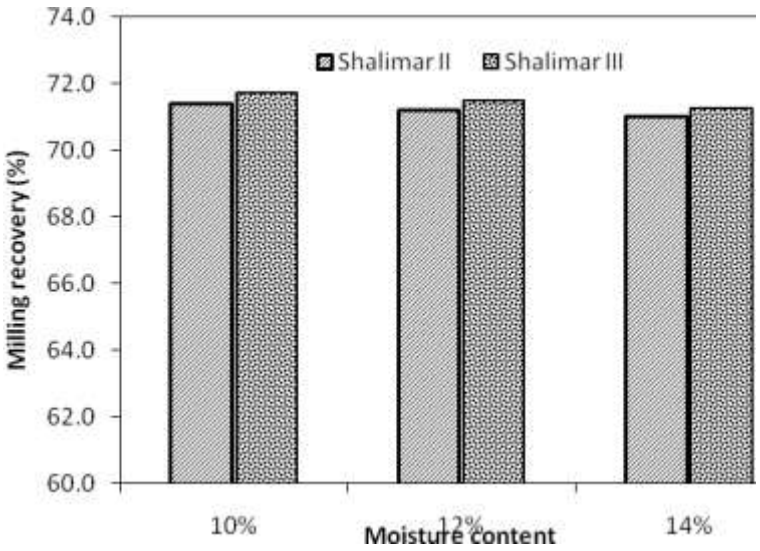

Figure 1 Effect of grain moisture content on milling recovery (MR) of Shalimar II and III paddy varieties

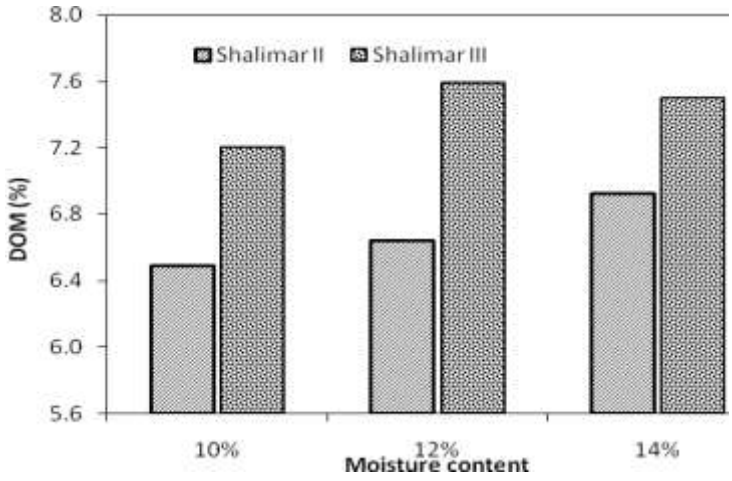

Figure 2 Degree of milling (DOM) of Shalimar II and III paddy varieties as affected by grain moisture

3.3 Degree of milling

The extent to which removal of bran from rice grains takes place is termed as degree of milling. The degree of milling of Shalimar II and Shalimar III rice grains is depicted in Fig. 2. The degree of milling for Shalimar II paddy conditioned at 10, 12 and 14 % moisture content was 6.49, 6.64 and 6.92 %, respectively whereas corresponding values for same in Shalimar III grains were 7.20, 7.59 and 7.50 %. The results show an evident effect of moisture content on degree of milling for both paddy varieties. Shalimar II paddy grains conditioned to moisture content of 14 % provided higher values for degree of milling whereas moisture content of paddy set to 12 % in Shalimar III resulted in higher bran removal percentage. The overall degree of milling of Shalimar III paddy kernels was higher depicting the presence of higher percentage of bran in their grains. The increase in DOM of paddy kernels with increasing moisture content has also been reported for two varieties of paddy at different moisture contents by Nasirahmadi et al. [22] whereas similar results were also reported by Andrews et al. [23] and; Reid et al. [24].

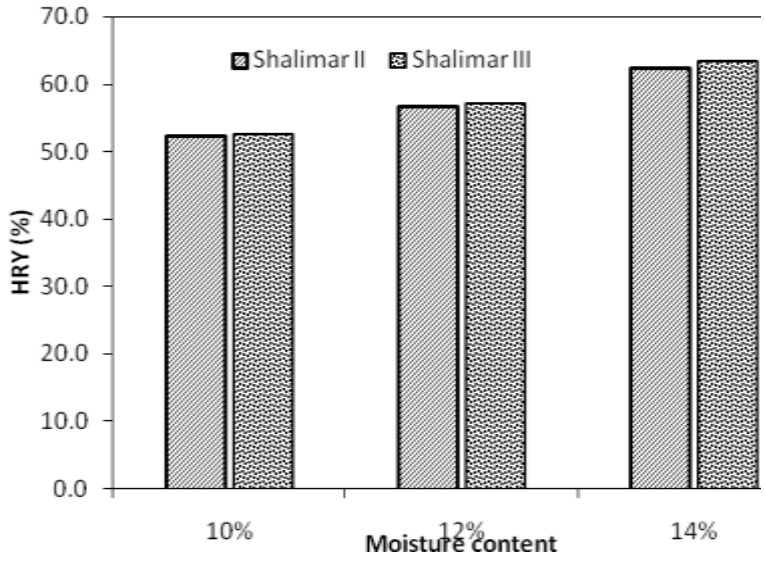

Figure 3 Effect of grain moisture content on head rice yield (HRY) of Shalimar II and III paddy varieties

3.4 Head rice yield (HRY)

The head rice is dependent on major dimensional property (length) of grains and includes any grain that is greater than 75 % of kernel length and below that size it is termed as broken rice [25]. Fig. 3 shows the effect of moisture content on head rice yield of two paddy varieties. The head rice yield of Shalimar II and III at 10 % moisture was 52.21 and 52.58 %, respectively. Paddy grains of Shalimar II with moisture content of 12 and 14 % presented head rice yield of 56.63 and 62.35 %, respectively. Shalimar III conditioned to 12 and 14 % moisture content yielded a hear rice yield of 57.17 and 63.34 %, respectively. The head rice yield of any paddy variety is important in predicting its suitability of use and market value. The rice brokens are undesirable and therefore a rice variety with low head rice yield or higher rice brokens has a lower market value [9, 26]. The effect of moisture content on head rice yield was apparent and lower moisture content were associated with

producing more rice brokens in both Shalimar II and Shalimar III rice varieties. The knowledge of head rice yield is an important predictor of marketability of kernels and in order to lower damage of head rice during milling paddy grains must be conditioned to proper moisture content prior to milling process. The higher head rice in case of Shalimar II and Shalimar III rice varieties was obtained when grains were conditioned at 14 % moisture content. Similar results on head rice yield of rice grains were shown by Ilieva et al. [21] and Nasirahmadi et al. [22].

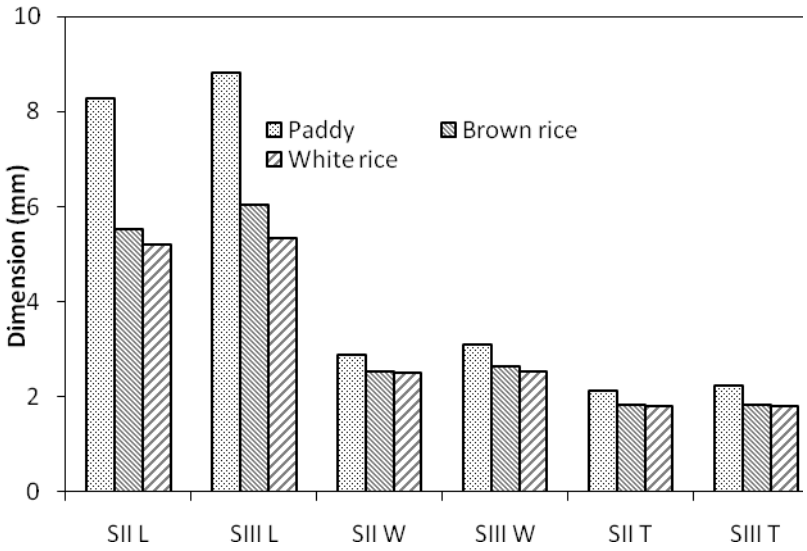

Figure 4 Changes in different grain dimensions of Shalimar II and III paddy varieties due to milling operation; SII-Shalimar II, SIII-Shalimar III, L-length, W-width and T-thickness.

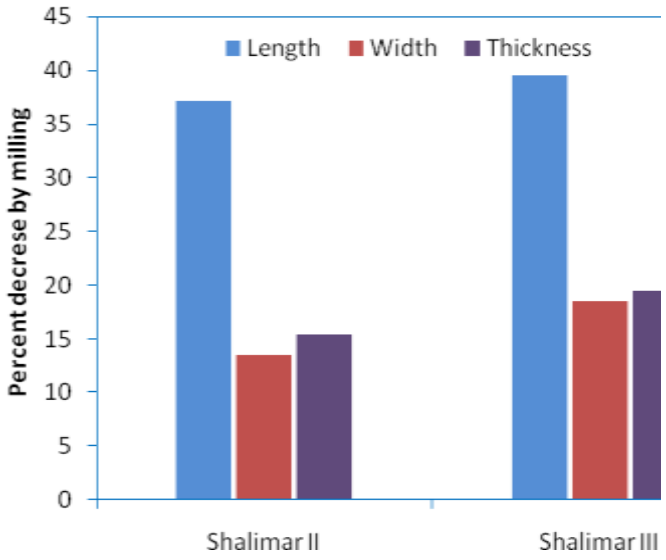

Figure 5 Percent decrease in the different dimensions of paddy due to milling of grains

3.5 Dimensional changes in milling

The paddy grains of Shalimar II and Shalimar III conditioned at 14 % moisture content were milled and the grains were analysed for their dimensional characteristics. The effect of milling on length of Shalimar II and Shalimar III grains is shown in Fig. 4. An evident and large decrease in length of paddy to brown rice was observed in both Shalimar II and III rice varieties and the decrease from brown to white rice was comparatively very small. Paddy grains of Shalimar II and III rice varieties had an initial length of 8.27 and 8.81 mm, respectively that decreased to 5.52 and 6.04 mm upon hulling and yielding brown rice. The length of brown rice was further reduced to 5.20 and 5.34 for Shalimar II and III, respectively due to polishing. The decrease in length from paddy to white rice is graphically depicted in Fig. 5 with about a decrease of 37.10 and 39.47 % respectively observed for Shalimar II and Shalimar III rice varieties.

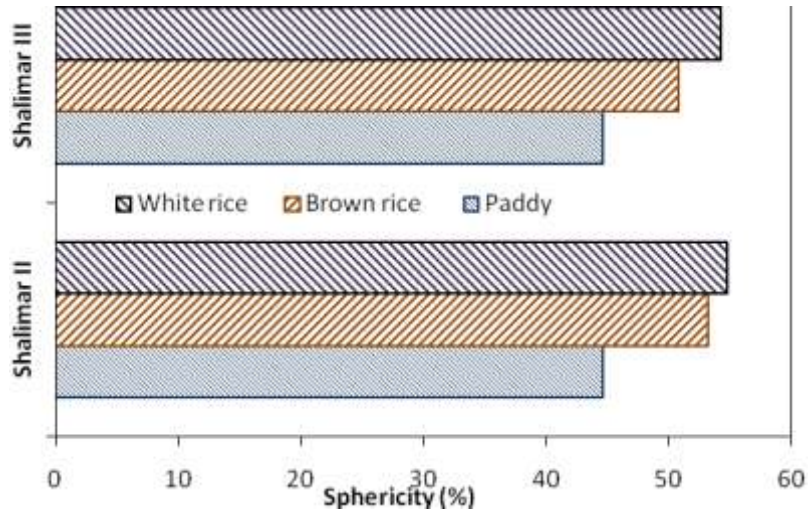

Figure 6 Effect of milling on sphericity of Shalimar II and Shalimar III rice grains

Similar results were shown by width and thickness of grains with transition of paddy to brown rice displaying large decrease and a smaller decrease from brown to white rice in respective dimensions. The changes in width and thickness of Shalimar II and III rice varieties are shown in Fig. 4. The respective width and thickness of paddy or rough rice was 2.88 and 2.12 mm for Shalimar II whereas similar values for Shalimar III were 3.10 and 2.24 mm. The width of brown rice of Shalimar II and III was reduced to 2.49 and 2.53 mm from 2.53and 2.62 mm, thereby yielding respective forms of white rice. Brown rice of Shalimar II and III had a thickness of 1.82 and 1.83 mm that upon polishing and transformation into white rice was reduced to 1.79 and 1.80 mm, respectively. The decrease in dimensions from paddy to white rice in graphically depicted in Figure 6 and a reduction of about 13.14 and 18.54 % in with and 15.35 and 19.47 in thickness of Shalimar II and Shalimar III was observed respectively. Similar changes in dimensions of paddy due to milling were observed by different studies as reported in literature [5, 27, 28, 29].

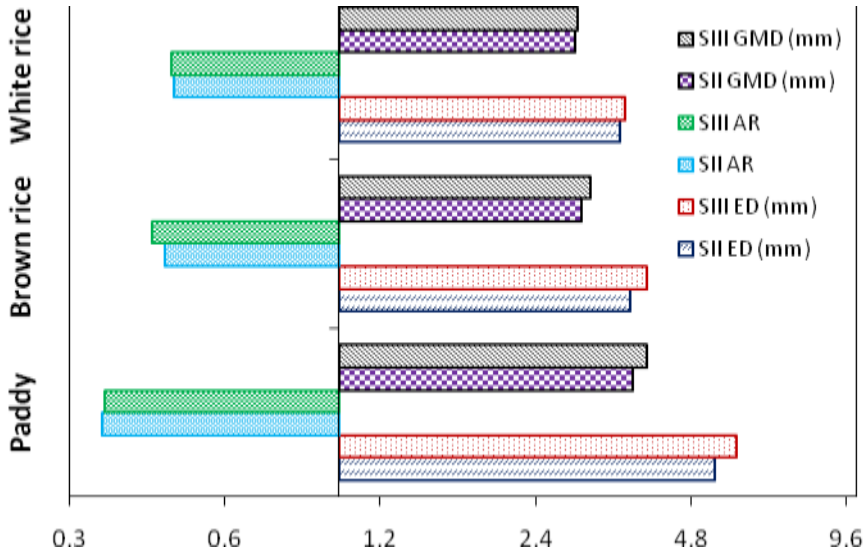

Figure 7 Changes in geometric mean diameter (GMD), angle of repose (AR) and equivalent diameter (ED) of Shalimar II (SII) and Shalimar III (SIII) kernels.

A gradual increase in sphericity of grains was witnessed with milling operation in both paddy varieties with an increment of 54.86 and 54.29 % from 44.68 and 44.71 % for Shalimar II and Shalimar III rice varieties, respectively. The graphical representation showing increase in sphericity of paddy grains is depicted in Fig. 6. Studies of Reddy and Chakraverty [30] and Haq et al. [5]) also observed similar changes in sphericity of paddy grains during their milling process. In contrast to sphericity both geometric mean diameter (GMD) and equivalent diameter decreased with processing of paddy to white rice (Fig. 7). The GMD of Shalimar II grains declined to 2.85 mm from 3.69 mm with processing whereas in Shalimar III the values reduced to 2.89 mm from 3.94 mm. The knowledge of GMD is important in pneumatic separation process of grains by providing projected area of particle in an air stream [31]. Similar results were also revealed by equivalent diameter with a decrease of about 32.62 and 39.26 % for Shalimar II and III varieties, respectively during their development of white rice from paddy. The aspect ratio of paddy grains increased during milling of grains (Fig. 7) with paddy, brown and white rice increasing aspect ratio of Shalimar II as 0.35, 0.45 and 0.47. The aspect ratio increased to 0.47 from 0.35 for Shalimar III rice grains with former values related to white rice and latter to paddy. The variation in dimensional characteristics was significantly high between paddy and brown rice whereas in case of brown and white rice the difference was considerably reduced and in some cases not evident at all.

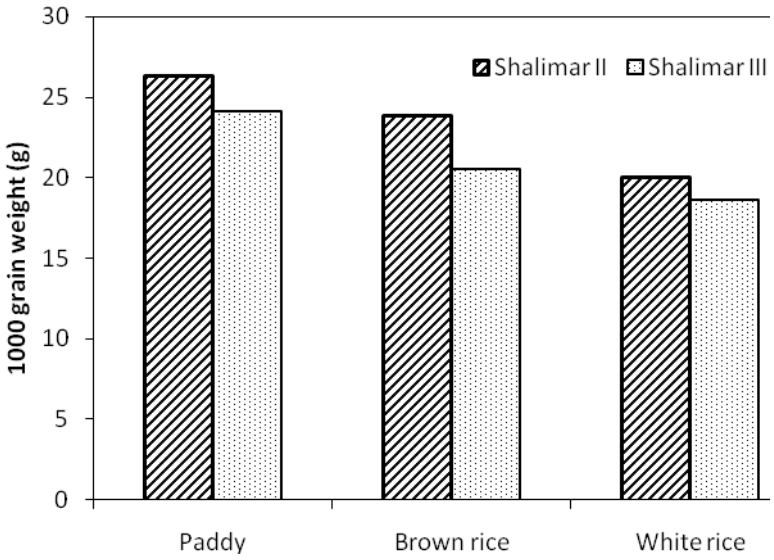

Figure 8 Variation in thousand kernel weight of paddy, brown and white rice grains from two paddy varieties.

3.6 Thousand kernel weight

The thousand kernel weight of rice grains in different forms belonging to Shalimar II and Shalimar III are shown graphically in Fig. 8. The successive removal of husk and bran from the paddy grains reduced their 1000 kernel weight in both paddy varieties. The 1000 grain weight decreased to 20.03 and 18.62 g from 26.31 and 24.13 g in Shalimar II and III paddy varieties, respectively. The visualization of different dimensional properties along with 1000 kernel weight categorized the varieties as paddy with short and bold grains as per USDA and FAO classification of grains [32, 33]. The results of current study categorize Shalimar II and Shalimar III rice grains as medium paddy varieties.

4. CONCLUSION

The milling of paddy grains conditioned with different moisture contents (10, 12 and 14 %) yielded white rice with milling recovery ranging from 71.22 to 71.72 % for Shalimar II whereas for Shalimar III the range of recovery was 71.03 to 71.72 %. The reduction in moisture of grains hindered the removal of bran removal in both paddy varieties. The paddy conditioned to 14 % moisture content yielded higher HRY with values increasing to 62.35 % from 52.21 % for Shalimar II while as in case of Shalimar III the HRY increased to 63.34 % from 52.58 %. The investigation revealed that for higher HRY the grains need to be conditioned to 14 % moisture prior to milling. The length of grains decreased by 37.10 and 39.47 % due to milling of Shalimar II and III grains, respectively, while as the width of corresponding grains declined by 13.46 and 18.54 %. The thickness of Shalimar II was reduced up to 15.35 % whereas for Shalimar III it was reduced by 19.47 %. The dimensions along with kernel weight and length breadth ratio placed the paddy grains of Shalimar II and III in short and bold category of classification system for grains.

REFERENCES

[1] Z. Zhout, K. Robards, S. Helliwell, and C. Blanchard, Ageing of stored rice: changes in chemical and physical attributes, Journal of Cereal Science, 35, 2002, 65–78.

[2] F. Courtois, M. Faessel, and C. Bonazzi, Assessing breakage and cracks of parboiled rice kernels by image analysis techniques, Food Control, 21(4), 2010, 567–572.

[3] FAOSTAT, *Rice Production statistics*, (FAO's Corporate Database 2016), Accessed, 3rd February 2018, from http://faostat.fao.org.

[4] K. Prasad, P. Prakash, and K.K. Prasad, *Rice based functional cookies for celiac: studies on its formulation*, (Lambert Academic Publishing, Saarbrucken Germany, 2010).

[5] R. Haq, M. Wani, and K. Prasad., Engineering properties of high and low altitude rice varieties from Kashmir valley at different processing levels, *Cogent Food & Agriculture*, 2, 2016, 1133371.

[6] R.N. Kaw, Characterization of the most popular rice varieties in low temperature areas of India and Nepal, Philippines Journal of Crop Science, 10, 1985, 1-6.

[7] FAO, *FAO/WFP Crop and Food Security Assessment Mission* (Special reports and alerts, document repository, 2011), Accessed, 3rd February 2018, Available from http://www.fao.org/docrep/013/al976e/al976e00.htm.

[8] H.S. Gujral, J. Singh, N.S. Sodhi, and N. Singh, Effect of milling variables on the degree of milling of unparboiled and parboiled rice, International Journal of Food Properties, 5(1), 2002, 193–204.

[9] USDA, *Inspection handbook for the sampling, inspection, grading, and certification of rice HB918-11*, (Washington, DC, USA, 1990).

[10] K. Gravois, Optimizing selection for rough rice yield head rice and total milled rice, Euphytica, 101(2), 1998, 151–156.

[11] W. Liu, and Y.Tao, T.J. Siebenmorgen, and H. Chen, Digital image analysis method for rapid measurement of rice degree of milling, Cereal Chemistry, 75(3), 1998, 380–385.

[12] A. Iguaz, M. Rodríguez, and P. Vírseda, Influence of handling and processing of rough rice on fissures and head rice yields, Journal of Food Engineering, 77(4), 2006, 803–809.

[13] H. Sun, and T.J. Siebenmorgen, Milling characteristics of various rough rice kernel thickness fractions. Cereal Chemistry, 70(6), 1993, 727–733.

[14] M.G. Varnamkhasti, H. Mobli, A. Jafari, S. Rafiee, M.H. Soltanabadi, and K. Kheiralipour, Some engineering properties of paddy (var *sazandegi*), International Journal of Agriculture and Biology, 9, 2007, 763-766.

[15] B.S. Luh, *Rice: production and utilization*, (AVI Press, Westport CT, USA, 1980)

[16] N.N. Sarker, and M. Farouk, Some factors causing rice milling loss in Bangladesh, AMA-Agricultural Mechanization in Asia Africa & Latin America, 20, 1989, 49–52.

[17] D. Mohapatra, and S. Bal, Effect of degree of milling on specific energy consumption, optical measurements and cooking quality of rice, Journal of Food Engineering, 80(1), 2007, 119–125.

[18] Z. Pan, K.S.P. Amaratunga, and J.F. Thompson, Relationship between rice sample milling conditions and milling quality, American Society of Agricultural and Biological Engineers, 50(4), 2007, 1307–1313.

[19] N.N. Mohsenin, *Physical properties of plant and animal materials*, (2nd ed Gordon and Breach Science Publishers, New York, 1986).

[20] K. Nalladulai, K. Alagusundaram, and P. Gayathri, Airflow resistance of paddy and its byproducts, Biosystems Engineering, 83, 2002, 67–75.

[21] V. Ilieva, I. Karov, L. Mihajlov, N. M. Ruzdik, and M. Ilievski, Effect of rice moisture at harvest and rough rice storage time on milling yield and grain breakage, Proc In: International Scientific Conf. on Breeding and Technologies Field Crops, Karnobat, Bulgaria, 2014, 27-28.

[22] A. Nasirahmadi, B. Emadi, M.H. Abbaspour-Fard, H. Aghagolzade, Influence of moisture content, variety and parboiling on milling quality of rice grains, Rice Science, 21(2), 2014, 116−122.

[23] S.B. Andrews, T.J. Siebenmorgen, and A. Mauromoustakos, Evaluation of the McGill No. 2 rice miller, Journal of Cereal Chemistry, 69(1), 1992, 35–43.

[24] J.D. Reid, T.J. Siebenmorgen, and A. Mauromoustakos, Factors affecting the slope of head rice yield vs. degree of milling, Journal of Cereal Chemistry, 75(5), 1998, 738–741.

[25] A.K. Thakur, and A.K. Gupta, Two stage drying of high moisture paddy with intervening rest period. Energy Conversion and Management, 47, 2006, 3069-3083.

[26] R.C. Bautista, T.J. Siebenmorgen, and A. Mauromoustakos, The role of rice individual kernel moisture content distributions at harvest on milling quality, Trans. of the ASABE, 52 (5), 2009, 1611-1620.

[27] S.J. Sujatha, R. Ahmad, and P.R. Bhat, Physicochemical properties and cooking qualities of two varieties of raw and parboiled rice cultivated in the coastal region of Dakshina Kannada, India, Food Chemistry, 86, 2004, 211-216.

[28] N. Singh, L. Kaur, N.S. Sodhi, and K.S. Sekhon, Physicochemical, cooking and textural properties of milled rice from different Indian rice cultivars, Food Chemistry, 89, 2005, 253–259.

[29] M.G. Varnamkhasti, H. Mobli, A. Jafari, A.R. Keyhani, M.H. Soltanabadi, S. Rafiee, and K. Kheiralipour, Some physical properties of rough rice (*Oryza sativa* L) grain, Journal of Cereal Science, 47, 2008, 496-501.

[30] B.S. Reddy, and A. Chakraverty, Physical properties of raw and parboiled paddy, Biosystems Engineering, 88, 2004, 461-466.

[31] T.O. Omobuwajo, E.A. Akanda, L.A. Sanni, Selected physical, mechanical and aerodynamic properties of African breadfruit (*Treculla Africana*) seeds. Journal of Food Engineering, 40, 1999, 241–244.

[32] T. Chang, and E.A. Bardenas, *Morphology and varietal characteristics of the rice plant*, (International Rice Research Institute, Laguna, Philippines, 1965).

[33] K.R. Bhattacharya, *Rice quality: a guide to rice properties and analysis*, **(**Woodhead Publishing Limited, Sawston Cambridge, UK, 2011).