Rather et al., *Cogent Food & Agriculture* (2016), 2: 1178694
http://dx.doi.org/10.1080/23311932.2016.1178694

cogent food & agriculture

Received: 14 March 2016
Accepted: 12 April 2016
Published: 05 May 2016

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Reviewing editor:
Fatih Yildiz, Middle East Technical University, Turkey

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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Physical, milling, cooking, and pasting characteristics of different rice varieties grown in the valley of Kashmir India

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Abstract: In the present study, three different rice varieties, namely frome chena (FC), safaid chena (SC), and barkat chena (BC), were evaluated for various quality aspects in terms of physical, milling, cooking, and pasting characteristics. Among the three rice varieties SC had the highest thousand kernel weight and length breadth ratio (L/B). While as, BC had the lowest thousand kernel weight and FC had lowest L/B. Bulk density was found to be highest for FC followed by SC and BC. FC had density of 769.01 kg/m^3. Milling characteristic in terms of broken percentage and head rice yield showed non-significant difference between the varieties. Head rice yield was below 70% in all the three varieties. All the three varieties took similar time to cook and cooking time varied non-significantly between 23.66 and 25.83 min. L/B ratio after cooking was found to be highest for FC followed by BC and SC. Elongation ratio of rice after cooking did not varied significantly between varieties. Elongation ratio after cooking ranged from 1.60 to 1.70. Pasting profile of rice flour was determined using rapid visco analyzer. Significant difference was observed in pasting profile of studied rice varieties.

Subjects: Agriculture & Environmental Sciences; Food Chemistry; Food Engineering; Food Science & Technology

Keywords: physical properties; milling characteristic; cooking characteristic; pasting properties

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PUBLIC INTEREST STATEMENT

Equipments are used for better handling of food crops. During the course of crop processing from harvesting to final consumption of produces different unit operation are involved. All these unit operations are carried out using different equipment. Grain characteristic determine the type of equipments better suited for them. Equipments used for handling, transport, processing, and storing the crop are designed based on the physical properties of grain. Cooking characteristics of rice grains will be useful in the design the cooking equipment, which could provide a solution to the over-cooked or under-cooked rice grains. Market value of rice grains is also determined by cooking characteristics. Losses during milling could be avoided by designing the milling equipment best suited for a particular grain. Knowledge of milling characteristic of grains could make designing of such type of equipment possible.

1. Introduction

Rice (*Oryza sativa* L.) is the most important cereal grain grown in the world. It is the staple food of nearly half of the world population. It is a regular Asian diet, usually taken as a whole grain after cooking, contributing about 40–80% of total calorie intake (Sarowar Hossain, Kumar Singh, & uz-Zaman, 2009). It is mostly consumed at household level as boiled or fried rice. The preference for taste, color, and stickiness of rice varieties varies among different cultures. The two most important cultivated species of rice are *Oryza sativa* and *Oryza glaberriumn*. *Oryza sativa* is grown in most parts of the Asian and American continents, whereas *Oryza glaberriumn* is grown only in Africa. Indica (long grain), Japonica (round grain), and Jayanica (medium grain) are three subspecies of rice grown in world. Rice consists mainly of carbohydrates in the form of starch, 72–75% of which contributes to the total grain composition. About 7% of protein mainly glutelin is present in rice. The glutelin present in rice is also called as oryzenin.

For the designing of equipment for handling, conveying, separation, dehulling, drying, storage, and other processes, physical properties of rice need to be studied. Knowledge of principle axial dimensions of a grain is useful in power calculation for milling and sieve selection for separation (Singh, Kaur, & Singh, 2015). They can also be useful in calculating volume and surface area of kernel which are important in modeling of grain drying, heating, cooling, and aeration. Density values are useful in sizing grain hoppers and storage facilities. Rate of heat and mass transfer during aeration and drying depends upon density values of grains (Malik & Saini, 2016).

The cooking qualities of rice determines their economic values, which can be measured in terms of cooking time, grain elongation during cooking, and length breadth ratio after cooking. Cooking quality depends upon the physical and chemical characteristics of starch, such as amylose–amylopectin ratio, gel consistency, and gelatinization temperature (Tan, Li, Yu, Xing, & Xu, 1999). Amylose content is one of the important characteristics influencing the cooking behavior (Xie, Chen, Duan, Zhu, & Liao, 2007). Rice variety with more than 25% of amylose content absorbs more water and has a fluffy texture after cooking (Frei, Siddhuraju, & Becker, 2003). Linear elongation of rice upon cooking is considered one of the major characteristics of good rice. Rice which expands only along length without increase in girth is considered high-quality rice (Sood & Sadiq, 1979). Gelatinization temperature has a direction relationship with grain elongation during cooking. Perez, Juliano, Pascual, and Novenario (1987) reported that rice with high gelatinization temperature elongates less during cooking.

Milling is an important unit operation in processing of rice, accuracy, and efficiency of milling machine along with grains behavior during milling largely determine the market value of grain. The main aim of milling is to get edible, white rice kernel that is sufficiently milled and free of impurities (Singh et al., 2015). The byproducts of milling are husk, germ, bran layers, and broken rice. The most important parameter of rice processing is the percentage of whole or head rice. To the best of our knowledge, there is no literature available regarding the characterization of rice varieties grown in Kashmir valley. Therefore, the objective of present study was to study the physical, cooking, pasting, and milling characteristics of three different varieties of rice from Kashmir.

2. Materials and methods

2.1. Materials

In this study, three rice varieties, namely frome chena (FC), safaid chena (SC), and barkat chena (BC) were procured from local miller and transported to laboratory of Islamic University of Science and Technology Awantipora Pulwama for analysis.

2.2. Physical analysis

2.2.1. Thousand grains weight
Thousand grain weight (g) was determined by weighing 100 grains in an electronic balance to an accuracy of 0.001 g and then multiplying by 10 to get the mass of 1,000 grains.

2.2.2. Length–breadth ratio (L/B)
For analyzing length–breadth ratio, the cumulative measurements of rice were measured in mm (n = 10) and the value of L/B was recorded by dividing length by breadth (Thomas, Wan, & Bhat, 2013).

2.2.3. Bulk density
The bulk density (ρ_b), which is defined as the ratio of the mass of sample to its total volume, was determined by following formula:

$$\rho_b = \left(kg \big/ m^3\right) = Ms/V$$

where Ms is the mass of grain and V is the volume occupied.

2.3. Cooking properties

2.3.1. Cooking time
Determination of cooking time was done by boiling 2.0 g of whole rice kernel in 20 ml distilled water, removing a few kernels at different time intervals during cooking, and pressing them between two glass plates until no white core was left. Optimum cooking time was taken as the established cooking time plus two additional minutes.

2.3.2. Elongation ratio
To determine elongation ratio, randomly selected cooked rice samples were measured for length and were divided by length of uncooked raw samples. Results were reported as elongation ratio.

2.3.3. Cooked rice length–breadth ratio
The length–breadth ratio was determined by dividing the cumulative length by the breadth of cooked kernels. A mean of 10 replicates were taken for measurement.

2.4. Pasting properties
The pasting properties of the rice flour were measured using a Rapid Visco Analyzer (Tech Master, Make Pertain Instruments Warriewood, Australia) according to the American Association of Cereal Chemists (2000). An aqueous dispersion of flour—14% moisture basis (10.7%, w/w; 28 g total weight)—was equilibrated at 50°C for 1 min, heated at the rate of 12.2°C /min to 95°C, held for 2.5 min, cooled to 50°C at the rate of 11.8°C /min and again held at 50°C for 2 min. A constant paddle rotational speed (160 rpm) was used throughout the entire analysis, except for rapid stirring at 960 rpm for the first 10 s to disperse the sample.

2.5. Milling properties

2.5.1. Broken percentage
The broken grains were separated from the whole grains. The percentage of the broken rice was calculated using the following equation (Ravi, Menon, Gomathy, Parimala, & Rajeshwari, 2012):

$$\text{Percentage brokens} = \frac{\text{Weight of broken grains}}{\text{Weight of paddy sample}} \times 100$$

2.5.2. Head rice percentage

The broken grains were separated from the whole grains. The percentage of the head rice was calculated using the following equation (Ravi et al., 2012):

$$\text{Percentage head rice yeild} = \frac{\text{Weight of whole grain}}{\text{Weight of paddy sample}} \times 100$$

2.6. Statistical analysis

SPSS software 16.0 was used to carry out the analysis of variance test to examine the varietal difference in physical, cooking, pasting, and milling characteristics of rice followed by Duncan's test ($p < 0.05$).

3. Results and discussion

3.1. Physical properties

Physical characteristic of three cultivars of rice grown in Kashmir valley is shown in Table 1. The bulk density values showed significant ($p < 0.05$) differences among the varieties, this may be due to the intrinsic characteristics of each variety. Among the three varieties, studied FC had the highest bulk density and BC had the lowest. Density values are useful in design of silos and storage bins (Nalladurai, Alagusundaram, & Gayathri, 2002). Since bulk density of BC is the lowest than FC and SC, BC will require a large silos compared to the other two varieties. Similar results were reported by Corrêa, da Silva, Jaren, Afonso, and Arana (2007) for Urucuia, Confianca, and Jequitiba varieties and Zareiforoush, Komarizadeh, and Alizadeh (2009) for Alikazemi and Hashemi varieties. Thousand grain weight showed significant difference and varied from 21.73 to 23.30 g. SC had the highest thousand grain weight and BC had the lowest. Diako et al. (2011) found that the imported brands had lower thousand grains weight. Values of thousand grains weight between 20 and 30 g are considered good while those less than 20 g could be indicative of the presence of immature, damaged, and unfilled grains (Adu-Kwarteng, Ellis, Oduro, & Manful, 2003). Low thousand grain weight may due to the low moisture content which increases the probability of more damaged grains during milling. There was no significant difference in the l/b ratio between rice varieties studied. The values of l/b ratio could be used to determination the shape of individual rice grain. An l/b ratio of above 3 is generally considered as slender and below 3 is generally considered as bold (IRRI International Rice Research Institute, 1980). L/b value of all the varieties studied was below 3.0; hence, they can be considered as bold. According to McKenzie and Rutger (1983) cooking and eating qualities of rice are strongly influenced by shape and width of grains, hence determining the shape and width of grain is essential.

3.2. Cooking properties

The cooking properties of rice are important as it is consumed almost immediately after cooking. Rice being a major staple food in most of the developing countries, reduced cooking time can be beneficial, especially when fuel consumption is of concern. Cooking time of a rice grain is usually ascertained when 90% starch of grain no longer shows an opaque center (Dipti, Bari, & Kabir, 2003). The cooking characteristics (cooking time, l/b ratio, and elongation ratio) of three rice varieties are shown in Table 2. The varietal difference showed non-significant effect on cooking time. Cooking time varied between 23.66 and 25.83 min. Variation in cooking time can be attributed to the

Table 1. Physical properties of three different rice varieties

Rice samples	Bulk density (kg/m^3)	Thousand kernal weight (g)	L/B ratio before cooking
Forme Chena	$769.01^a \pm 4.0$	$22.73^b \pm 0.35$	$2.28^a \pm 0.04$
Safaid Chena	$564.06^b \pm 137.4$	$23.30^b \pm 0.43$	$2.36^a \pm 0.16$
Barkat Chena	$502.00^c \pm 62.48$	$21.73^a \pm 0.04$	$2.30^a \pm 0.15$

Note: Mean values in the same column bearing the same superscript do not differ significantly ($p > 0.05$).

Table 2. Cooking properties of three different rice varieties			
Rice samples	**Cooking time (min)**	**Elongation ratio**	**L/B ratio after cooking**
Forme Chena	$23.66^{a} \pm 1.52$	$1.70^{a} \pm 0.10$	$3.91^{b} \pm 0.27$
Safaid Chena	$23.83^{a} \pm 0.76$	$1.60^{a} \pm 0.16$	$2.83^{a} \pm 0.17$
Barkat Chena	$25.83^{a} \pm 1.04$	$1.63^{a} \pm 0.13$	$2.63^{a} \pm 0.04$

Note: Mean values in the same column bearing the same superscript do not differ significantly ($p > 0.05$).

presence or absence of bran layer on grains. Higher cooking time is required for rice varieties having fibrous bran layer attached (Juliano & Bechtel, 1985). In terms of fuel and energy consumption during cooking, lower cooking time is better. The variation in the cooking time could also be attributed to its gelatinization temperature, since gelatinization temperature positively determines the cooking time of rice. It has been asserted that the higher the value of gelatinization temperature, the longer time it takes to cook rice. According to Bhattacharya and Sowbhagya (1971), cooking time is primarily related to the surface area of the milled rice and unrelated to other grain properties. L/B ratio after cooking was observed to be highest for FC variety. Change in length or breadth during cooking is directly related to the change in volume. Lengthwise increase on cooking is preferred and is characteristics of a high-quality rice variety, while as increase in breadth is considered as an undesirable trait (Danbaba, Anounye, Gana, Abo, & Ukwungwu, 2011). Elongation of rice after cooking did not showed significant variation among the three varieties. Elongation ratio ranges from 1.60 to 1.70. Danbaba et al. (2011) reported that both l/b ratio and amylose content influence the elongation ratio of rice. FC variety had the highest l/b ratio and hence had the higher elongation ratio as well (Table 2). Over-cooking of grain affects the elongation as it may lead to disintegration and curling of the cooked rice. Juliano et al. (1982) recommended that under-cooking is the best option under these conditions to avoid curling of cooked rice.

3.3. Pasting properties

The eating quality of rice can be determined indirectly from RVA profile of rice flour. Table 3 shows the pasting profile for three rice varieties includes peak, trough, breakdown, final, and setback viscosity along with pasting temperature and time. Pasting temperature indicates the initial increase in viscosity. The pasting temperature of BC and FC showed non-significant difference, however, SC showed significant ($p < 0.05$) difference with BC and FC. BC flour has the highest pasting temperature (78.63°C) followed by FC (76.52°C) and SC (51.86°C). This might be due the lower content of damaged starch in BC rice four; therefore, starch granules would absorb water slowly and swell slowly resulting in gelatinization of starch at higher temperature. The higher pasting temperature of BC suggested higher energy costs would be required during cooking. The pasting time showed a non-significant difference between the three varieties. The maximum viscosity obtained by gelatinized starch during heating is called as peak viscosity. It indicates the water holding capacity of the starch granule (Shimelis, Meaza, & Rakshit, 2006). It also indicates the beginning of granule disruption, when granule structure is unable to withstand continuous swelling (Zhong et al., 2009). Significant ($p < 0.05$) difference was found in peak, trough, breakdown, final, and setback viscosities for all the three varieties. SC was found with the highest peak viscosity (3,627.33 cp) and BC with the lowest (2,827.33 cp). Trough viscosity was the highest for FC (2,168.00 cp) followed by BC (1,967.33 cp) and SC (1,757.67 cp). Breakdown viscosity is regarded as measure of degree of disintegration of cooked starch and indicates the paste stability. Granules are disrupted during breakdown and consequently linear molecules are leached out into the solution (Asmeda, Noorlaila, & Norziah, 2016). SC was found with higher breakdown viscosity than BC and FC. All the three flours showed increase in viscosity after cooling, this is due the formation of viscous paste or gel between starch molecules (Kim & Shin, 2014). Higher final viscosity indicates that when pastes are cooled they have a potential to form a rigid gel structure. Final viscosity was found higher in SC (4,727.33 cp) followed by BC (4,263.00 cp) and FC (4,107.00). The increase in viscosity may be due to interaction between granule remnants and leached molecules and reinforcement of formed network (Waterschoot, Gomand, Willebrords, Fierens, & Delcour, 2014). Higher final viscosity indicates higher set back viscosity, which

Table 3. Pasting properties of rice flour

Rice samples	PT (°C)	PT (min)	PV (cP)	TV (cP)	BDV (cP)	SV (cP)	FV (cP)
Forme Chena	76.52^a ± 1.59	6.28^a ± 0.68	3166.67^a ± 14.34	2168.00^a ± 11.05	998.67^a ± 25.38	4107.00^a ± 13.95	1939.00^a ± 24.99
Safaid Chena	51.86^b ± 0.66	5.47^a ± 0.40	3627.33^b ± 20.98	1757.67^b ± 12.28	1869.67^b ± 8.73	4727.33^b ± 20.85	2969.67^b ± 8.58
Barkat Chena	78.63^a ± 0.46	6.54^a ± 0.36	2827.33^c ± 21.31	1967.33^c ± 12.66	860.00^c ± 8.83	4263.00^c ± 14.76	2295.67^c ± 2.62

Note: Mean values in the same column bearing the same superscript do not differ significantly ($p > 0.05$).

Table 4. Milling properties of three different rice varieties

Rice samples	Head rice (%)	Broken rice (%)
Forme Chena	68.65^a ± 1.20	31.43^a ± 1.20
Safaid Chena	66.50^a ± 1.83	32.83^a ± 0.70
Barkat Chena	66.33^a ± 0.55	33.66^a ± 0.55

Note: Mean values in the same column bearing the same superscript do not differ significantly ($p > 0.05$).

shows high degree of retreogrdation of gelatinized starch during cooling. FC variety had the lowest setback viscosity (1,939.00 cp), which indicates that this variety showed resistance to retrogradation during cooling (Abdel-Aal, Hucl, Chibbar, Han, & Demeke, 2002).

3.4. Milling properties

The milling characteristics of three rice varieties are shown in Table 4. The milling characteristics studied showed no significant difference between the varieties. Broken rice percentage ranges between 31.43 and 33.66% and head rice yield ranges between 66.33 and 68.56%. The non-significant difference in broken rice percentage and head rice yield can be attributed that all three varieties have non-significant difference in l/b ratio. Rice varieties with higher length are more susceptible to cracking and breakage during milling (Wiset, Srzednicki, Driscoll, Nimmuntavin, & Siwapornrak, 2001). Incorporation of the rice variety with high broken percentage influences the final products significantly with greater amylose content, harder gel, less swelling, lower volume expansion, and harder texture (Keeratipibul, Luangsakul, & Lertsatchayarn, 2008). According to Dipti, Hossain, Bari, and Kabir (2002), good quality rice will have a head rice yield of at least 70%, therefore, it can be claimed that these three rice varieties have an intermediate quality in terms of head rice yield percentage. Percentage of broken rice and head rice yield are significantly affected by moisture content before milling (Imoudu & Olufato, 2000).

4. Conclusion

The three rice varieties grown in Kashmir valley were evaluated for physical, cooking, pasting, and milling characteristics. The three varieties included FC, SC, and BC. FC had the highest bulk density compared to the SC and BC. Thousand kernel weight was observed to be highest for SC and lowest for BC. All varieties showed similar shape characteristic as l/b ratio did not differ significantly between the varieties. Milling behavior of all the three varieties was same. The broken rice percentage and head rice yield did not differ significantly between the varieties. It was observed that all the varieties had intermediate quality in term of head rice yield. Cooking characteristic did not differ significantly between the varieties. The rice varieties took 23.66–25.83 min to cook. FC variety increased in length after cooking, the increase in length after cooking is a desirable trait of rice and is mark of high-quality rice. The indirect eating quality assessment of rice can be obtained by studying the pasting profile of rice flour. BC variety requires higher temperature and more time for paste formation compared to the FC and SC. FC variety formed pastes with higher peak, breakdown, setback, and final viscosity. This pasting profile of FC can useful in dough and batter preparations. The varieties studied did not differ significantly for the studied characteristic. Therefore, further study is needed to figure out the differences in these selected varieties. The study could be on the nutritional and compositional analysis.

Funding
The authors received no direct funding for this research.

Competing Interests
The authors declare no competing interest.

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Citation information
Cite this article as: Physical, milling, cooking, and pasting characteristics of different rice varieties grown in the valley of Kashmir India, Tanveer Ahmad Rather, Mudasir Ahmad Malik & Aamir Hussian Dar, *Cogent Food & Agriculture* (2016), 2: 1178694.

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