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Physico-chemical and cooking characteristics of Azad basmati

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Abstract

The experiment was conducted to study grain quality characteristics of Azad Basmati and to compare with other prominent Basmati rice varieties. The result of an experiment on various milling characteristics of Basmati rice varieties, among which Azad basmati exhibited high hulling (73.53%), milling (65.77%) and the highest head rice out-turn, having long-slender, translucent, creamy white kernels. Kernel dimensions of Azad Basmati were satisfactory in respect of breadth (1.60 mm) and Length/Breath (L/B) ratio (3.93) but kernel length (6.28 mm) fell marginally short than the desired minimum kernel length for Basmati rice (6.6 mm). On cooking Azad Basmati exhibited highest kernel elongation ratio (KER) and volume expansion ratio (VER) 2.20 and 4.00, respectively. Azad Basmati turned-out to be the best in respect of hulling rice recovery (HRR) (62.67%) as compared with all the check varieties (43 to 50%). Kernel breadth and L/B ratio of Azad Basmati were comparable to most check varieties, however, fell marginally short in respect of grain length than the desired minimum acceptable standard of 6.6mm. All the check varieties except Basmati-370 were comparable to Azad Basmati in respect of volume expansion ratio (VER). All check varieties in respect of VER, KEaC and KER were not found to be significantly better than Azad Basmati excepting Basmati-370 and Pusa Basmati-1 in respect of VER and KEaC, respectively. Azad Basmati variety was high (22.8%) in amylose content (AC) as compared to evolved basmati varieties Basmati-370, Pusa Basmati-1 and Basumathi but found lower than Type-3 and Improve Pusa Basmati-1 and, Azad Basmati was found intermediate except Basumathi.

Introduction

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population. About 90% of the world's rice is grown and consumed in Asia (Tyagi *et al*., 2004). Rice is ranked as the world's number one human food crop (Itani *et al*., 2002) and an economically important food crop with nutritional diversification that helps in poverty alleviation (Otegbayo *et al*., 2001). Rice is mainly consumed in whole milled form. Rice milling is a combination of several unit operations to convert paddy into well-milled silky-white rice, which has superior cooking quality attributes. Grain quality of rice is determined by several factors such as grain appearance, nutritional value, cooking and eating quality. Rice is consumed principally as a whole grain and the texture of the whole grain is a matter of great concern. Rice quality is of great importance for all people involved in producing, processing and consuming rice, because it affects the nutritional and commercial value of grains. Grain quality is based upon objective and subjective criteria, the relative importance of which depends upon the particular end-use. The most important quality components, common to all users, include appearance, milling, cooking, processing and nutritional quality. Further grain quality has become an important issue affecting domestic consumption and international trade of rice (Lodh, 2002).

The physico-chemical characteristics include grain length, breadth, L/B ratio, hulling and milling percentage. The cooking qualities are amylose content (AC), alkali spreading value (ASV), water uptake (WU), volume expansion ratio (VER) and kernel elongation ratio (KER). Grain quality is a very wide area encompassing diverse characters that are directly or indirectly related to exhibit one quality type (Siddiqui *et al*., 2007). Different cultivars showed significant variations in morphological, physicochemical and cooking properties (Yadav *et al*., 2007). The gelatinization temperature (GT), gel consistency (GC) and AC are major rice traits, which are directly related to cooking and eating

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quality. On the other hand AC, amylopectin structure and protein composition explained the difference in cooking quality of rice (Lisle *et al*., 2000). The cooking quality of rice was determined on the basis of physicochemical properties and AC (Sujatha *et al*., 2004). Cooked rice is composite food consist of different biopolymers, including starch and proteins along with moisture as plasticizer (Ahmed *et al*., 2007). GT is responsible for cooking time, water absorption and the temperature at which starch irreversibly loses its crystalline order during cooking. The GC is responsible for softness and the AC for texture of cooked rice (Sabouri, 2009). Today, the consumers prefer to eat unpolished rice especially traditional rice because of the nutrient value in the bran and their reputation for nutritional excellence. Therefore the demands for brown and parboiled rice are increasing among the populations (Parnsakhorn and Noomhorm, 2008).

Azad Basmati (CSAR 839-3) is a high yielding rice variety of Basmati type for traditional and non-traditional Basmati growing areas, has recently been developed by the Scientists of CSA University of Agriculture and Technology, Kanpur (UP) – 208002 INDIA. Basmati rice grain is characterized by certain unique features which may be graded as export quality rice with normal nutritional quality. Under the above circumstances, the present investigation was undertaken with following specific objectives to determine milling, physical, thermal and cooking quality characteristics of Azad Basmati rice, and to compare the grain quality characteristics of Azad Basmati rice with other prominent basmati rice varieties.

Materials and Methods

Sample collection

The laboratory experiment was conducted in the Department of Agricultural Biochemistry, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (UP) India. For this purpose, paddy samples of six Basmati rice varieties namely- Azad Basmati (CSAR 839-3), Basmati-370, Type-3, Pusa Basmati-1, Improved Pusa Basmati-1 and Basumathi were procured from Rice Improvement Unit at C. S. Azad University of Agriculture and Technology. All the samples were brought to laboratory, transferred into cotton bags and stored at room temperature for analysis.

Hulling recovery

Hundred gram cleaned rough rice (paddy) sample was weighed and dehulled in a Laboratory through Dehusking Machine (Laboratory Rice Sheller, 6700, INDOSAW, Haryana, India); the weight of hulled rice was determined and hulling recovery was calculated by dividing the weight of hulled rice by total weight of rough rice sample, and multiplying by 100 (Dela-Cruz and Khush, 2000).

Milling recovery

Fifty gram brown rice was placed in the chamber of a Laboratory Polishing Machine (Laboratory Rice Grain Polisher, 6704, INDOSAW, Haryana, India) and processed for one minute. The weight of polished rice was determined and milling percentage was calculated by dividing the weight of milled rice by weight of brown rice (50 g) and multiplying by hulled rice recovery/100 g paddy (Dela-Cruz and Khush, 2000).

Head rice recovery and broken rice

Twenty gram milled rice sample was accurately weighted that had no visible breakage and whole rice kernel (3/4 size or more) were separated by hand and weighted. The head rice recovery was calculated by dividing the weight of head rice by weight of milled rice (20 g) and multiplying by milled rice recovery/100 g paddy. The percentage of HRR and BR were calculated using the standard formula (Dela-Cruz and Khush, 2000).

Test weight

Hundred whole and healthy paddy seeds were counted, weighed and test weight was calculated.

Translucency/chalkiness

Milled rice samples were visually observed for the presence of white patches in the kernels and the observation were recorded.

Kernel length, breadth, length/breadth ratio and grain classification

Ten randomly selected whole kernels of rice in three sets were taken and length of each grain was measured by placing on a micro-scale. Breadth of each grain was measured using a Vernier Caliper. The average of 10 such observations was taken for final reading of length and breadth of rice kernels in millimeter (mm). The L/B ratio was calculated by dividing the average length by the average breadth of rice kernel. Based on the L/B ratio, grains were classified (Dela-Cruz and Khush, 2000) into long slender (LS), short slender (SS), medium slender (MS), long bold (LB) and short bold (SB). Kernel length measurements on the basis of average length (mm), kernels were classified as follows: Extra long

(> 7.50), Long (6.61-7.50), Medium (5.51-6.60), and Short (< 5.50).

Seed grade

On the basis of average length/breadth ratio of the kernel, recorded as per above methods, the sample were categorized according to Ramaiah Committee (1969) into different grade as follows: Long Slender (Length > 6.00mm, L/B > 3.0), Short Slender (L < 6.00mm, L/B > 3.0), Long Bold (L > 6.00mm, L/B < 3.0), Medium Slender (L < 6.00mm, 2.5 < L/B > 3.0) and Short Bold (L < 6.00mm, L/B < 2.5).

Water uptake

Two gram rice sample was taken into a large test tube containing 10ml distilled water. The rice was cooked by placing the test tube in water bath at 77ºC for 35 minutes. The contents of the test tube were transferred into a glass funnels, lined with filter paper and fitted on a filtration flask, and the volume of unabsorbed water, recovered by using mild vacuum, and measured. The amount of water absorbed by sample was determined by subtracting the unabsorbed water volume from the original volume of water added (10 ml). Apparent water uptake on cooking (ml/100 g rice) was calculated by multiplying the absorbed water volume by 50 (Anonymous, 2004).

Volume expansion ratio

Two gram sample of rice was weighed into a graduated test tube and 5ml distilled water was added. Cooking was carried out by placing the test tube in Water bath at 77ºC for 35 minutes and the volume of the cooked rice was measured. The volume expansion ratio of rice after cooking was calculated in terms of original volume (Juliono, 1971).

Kernel elongation after cooking and kernel elongation ratio

The length of 10 whole rice kernels after cooking (as above in the volume expansion ratio) was measured by using the micro-scale, and the average kernel length determined. Kernel elongation ratio was calculated by dividing the average length of cooked kernel by the average length of the raw (uncooked) rice (Juliono, 1971).

Alkali spreading value/gelatinization temperature

Gelatinization temperature (GT) was estimated based on alkali spreading value (ASV) of milled rice. The method was used to score alkali spreading value. 10 ml of 1.7% potassium hydroxide (KOH) solution was placed in a small glass petri-dish and two sets of seven whole milled grains of rice were placed in the dish, spaced evenly. The kernels were arranged in such a way to provide space between kernels for spreading. The petri-dishes were covered and left undisturbed for 23hrs incubated at the room temperature. The extent of disintegration of kernel due to alkali was rated visually based on a 7-point numerical spreading scale (Little *et al*., 1958).

Gel consistency

Two sets of milled rice flour (100 mg) were taken in test tubes. To this, 0.2 ml of 95 per cent ethanol containing 0.025 per cent (w/v) thymol blue and 2.0 ml of 0.2 N KOH were added. Contents were mixed using a Vortex Genie mixer. The test tubes were covered with glass marbles in order to prevent steam loss and to reflux the samples. The samples were cooked in a vigorously boiling water bath for eight minutes to make the contents reach two third the height of the tube. The test tubes were removed from the water bath and kept at room temperature for five minutes. The tubes were kept in an ice water bath for twenty minutes and laid horizontally on a table, lined with millimeter graphing paper (Cagampang *et al*., 1971).

Amylose content

Amylose content (AC) of milled rice was measured by using the relative absorbancy of starch-iodine color in solution of 100-mesh rice flour digested according to the previous method (Perez and Juliano 1978). The paddy samples of six Basmati rice varieties are grouped on the basis of their amylose content into five groups as: waxy (0-2%), very low (3-9%), low (10-19%), intermediate (20-25%) and high (>25%) (Dela Cruz and Khush, 2000).

Statistical analysis

The observed data of the experiment were analyzed by the fixed affixed model using Completely Randomized Design (CRD). The method of analysis of variance employs least square method of estimation for estimating the treatment effects. The hypothesis of the quality of the treatment mean is tested by employing t-test and the quality of paired treatments is tested by t-test.

Results and Discussion

Milling characteristics

Milling quality of rice grains is important to both, producers and consumers as the market price of rice is largely dependent on milling performance. Millers base their concept of quality upon total recovery and the proportion of head and broken rice on milling,

Table 1. Mean performance of different physico-chemical and cooking characteristics of basmati rice genotypes

Quality Characteristics	Azad Basmati	Basmati 370	Type-3	Pusa Basmati-1	Improved P.B.-1	Basumathi
HR (%)	73.53	69.57	66.43	66.00	72.03	78.37
MR (%)	65.77	63.83	59.37	60.63	64.77	66.97
HRR (%)	62.67	47.33	45.07	43.07	50.07	45.70
BR (%)	02.07	15.40	17.47	16.67	13.77	23.73
TW (g)	21.33	21.57	20.17	22.13	24.63	20.57
KL (mm)	6.28	6.61	7.28	7.31	7.31	7.04
KB (mm)	1.60	1.54	1.51	1.58	1.58	1.70
L/B	3.93	4.29	4.82	4.63	4.63	4.14
WU (ml/100g)	860	674	799	849	949	674
VER	4.00	4.00	3.50	3.70	3.25	3.30
KEaC (mm)	12.80	12.40	12.47	14.50	11.20	14.25
KER	2.20	1.80	1.70	2.00	1.38	2.00
ASV (%)	6.5	4.5	6.5	7.0	6.0	4.5
AC (%)	22.80	22.03	23.00	22.17	23.12	15.86
Amylose Class	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Low

HR=Hulling Recovery, MR=Milling Recovery, HRR=Head Rice Recovery, BR=Broken Rice, TW= Test Weight, KL=Kernel Length, KB=Kernel Breadth, L/B =Length/Breath, WU=Water Uptake, VER=Volume Expansion Ratio, KEaC=Kernel Elongation after Cooking, KER=Kernel Elongation Ratio, ASV=Alkali Spreading Value and AC= Amylose Content

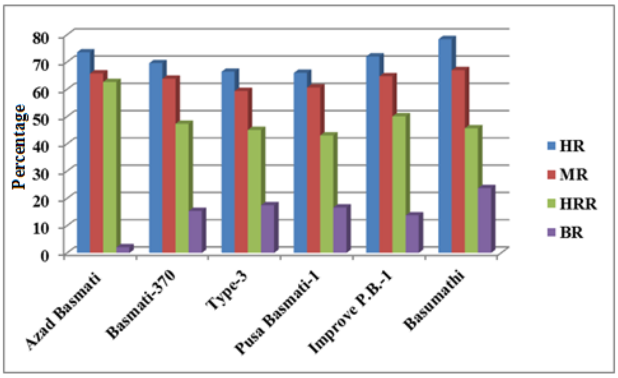

Figure 1. General and comparative presentation of milling characteristics

therefore a variety should possess a high turn-out of whole grain (head rice) and total milled rice (Webb and Stermer, 1985). In the present investigation, the test variety Azad Basmati was found to possess fairly high hulling (73.53%), milling (65.77%), head rice out-turn (62.67%) and very low broken rice (2.07%). When compared with the check varieties, Azad Basmati out-performed all the varieties in respect of head rice out-turn and was second only to Basumathi in respect of milling recovery (Table 1, Figure 1). Check variety Basumathi exhibiting highest hulling and milling yields (78.37 and 66.97%, respectively) turned-out to be inferior than Azad Basmati and rest of the check varieties (except Improved Pusa Basmati-1) in respect of head rice out-turn, the ultimate criteria of assessing milling characteristics. Milling recovery is reported to depend on grain shape and appearance, which has direct effect on the percentage of hulling, milling and head rice recovery. Normally, the hull content is 20 to 22% of the rough rice although a variation of 18 to 26% has been recorded. Bran and embryo (polish) account for another 8 to 10%. Thus, for a given sample of rice about 70% of milled rice is obtained (Khush *et al*., 1979). The range of variation observed in the present investigation for hulling (66.00-78.37%), milling (59.37-66.97%) and head rice out-turn (43.07-62.67%) is satisfactorily comparable to the reported values by Khush *et al*. (1979) for HRR (25-65%), Dipti et al. (2002) for milling out-turn (64-70%) and HRR (61-82%), Vanaja and Babu (2006) for milling (51.1-76.9%) and Hulling (67.3-79.6%), Parnsakhorn and Noomhorm (2008) for HRR (54.40-75.77%), Bhonsle and Sellappan (2010) for hulling (63-81%) and HRR (45-74%), respectively, Verma *et al.* (2013) observed in some promising basmati genotypes for hulling, milling and head rice out-turn were 72-80%, 64-7% and 52-61.9%, respectively, Lee *et al*., (2014) for HRR (54.1–63.1%). A significant relationship between hull weight and milling recovery has been reported by Shobha Rani *et al*. (2003). Besides grain size, shape, presence/absence of abdominal white etc. processing and type of mills employed have direct bearing on HRR (Bhattacharya, 1985).

Physical characteristics

Consumers base their concept of quality on the grain appearance, size and shape of the grain. The consumers prefer rice with a translucent endosperm and pay a premium price for it. Grain size and shape are the first criteria for rice quality that breeders consider in developing new varieties for release for commercial production (Adair *et al*., 1966). The classification of rice quality is based on the length of grain i.e. short, medium and long grain (Adu-kwarteng *et al*., 2003). The Basmati types are characterized by

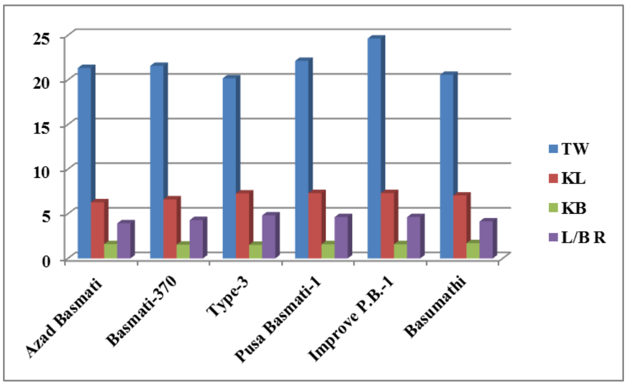

Figure 2. General and comparative presentation of physical characteristics

long, slender grains having kernel length of 6mm and more, L/B ratio of 3 and above, and high kernel elongation after cooking (Singh *et al.*, 2000). The grain elongation on cooking is dependent on genetic factors as well as the degree of milling (Mohapatra and Bal, 2006). In the present investigation, all the six varieties studied, including test variety, had long-slender, translucent, creamy white kernels; Check varieties having 6.61 to 7.31 mm kernel length, 1.51 to 1.70 mm breadth and 4.1 to 4.8 L/B ratio, thus, possess the physical characteristics for Basmati rice as indicated above (Singh *et al.*, 2000). However, the test variety Azad Basmati having 6.28 mm kernel length, 1.60 mm breadth and 3.93 L/B ratio was satisfactorily comparable in respect of grain breadth and L/B ratio but fell marginally short than the desired minimal kernel length (6 mm) for Basmati rice. Among the check varieties, Pusa Basmati-1, Type-3 and Improved Pusa Basmati-1 appeared to be better than the rest, in respect of physical characteristics (Table 1, Figure 2). Dipti *et al.* (2002) reported wide variation in grain length from 3.6 to 6.5mm and breadth from 1.7 to 3.7 mm in six fine rice varieties grown in Pakistan. Meena *et al*. (2010) found that the grain length varied from 4.30 to 7.80 mm, breadth 1.84 to 2.27 mm, and grain width 1.54 to 1.88 mm in selected aromatic rice varieties. Similar results were found by Sareepuang *et al.* (2008) the length and width of parboiled fragrant rice were ranged from 7.0 9.0 mm and 2.02-2.06 mm, respectively, which were greater and shorter than those of brown rice. Vanaja and Babu (2006) reported 7.35 to 10.11 mm and 2.56 to 3.76mm for grain length and breadth, respectively. Diako *et al*. (2011b) reported that the local varieties had bolder grains with their widths ranging from 2.21 to 2.26 mm compared with 1.96 mm for the imported varieties. Kanchana *et al.* (2012) reported 0.33 to 0.43 and 0.13 to 0.20 cm grain length and breadth, respectively in 41 rice varieties to know the physical qualities. Verma *et al*. (2013) found 6.81-7.34 mm (kernel length) and 1.70-1.93 mm (kernel breadth). Santhi and Vijayakumar (2014) reported 8.31-8.65 mm grain length and 3.00-3.04 mm breadth in pigmented brown rice. Samal *et al.* (2014) found grain length ranged from 4.90 to 12.41 mm and grain width was 1.80 to 3.50 mm in indigenous aromatic rice. Wide variation in L/B ratio from 2.21 to 4.12 (Itani *et al.*, 2002), 2.62 to 4.55 (Singh *et al.*, 2005), 1.95 to 3.85 (Vanaja and Babu, 2006), 1.5 to 3.5 (Bhonsle and Sellappan, 2010), 2.02 to 4.22 (Meena *et al.*, 2010), from 3.55 to 4.24 (Verma *et al.*, 2013) and from 1.69 to 5.86 (Samal *et al.*, 2014), have been reported. Thomas *et al.* (2013) was reported highest l/b ratio (3.75) for the local white rice, whereas, the lowest ratio was recorded for brown rice (2.09) in locally grown and imported rice varieties marketed in Penang, Malaysia. A length to breadth ratio of above 3 is generally considered as slender (IRRI, 1980). The analysis of l/b ratio was performed to determine the shape of individual rice grains.

Cooking characteristics

Cooking characteristics of rice are linked to consumer preferences for rice (Isono *et al.*, 1994; Bhattacharjee *et al.*, 2002) and are very important as rice is consumed almost immediately after cooking (Thomas *et al.*, 2013). Basmati rice has very interesting cooking qualities. It is non-waxy, non-glutinous rice and does not stick on cooking. It cooks flaky and remains soft on cooling and has a high volume expansion. Its elongation after cooking is also measured as the longest one, while its width remains the same (Bhattacharjee *et al*., 2002). Though cooking and eating characteristics of rice are mostly determined by the chemical composition of rice, especially content and structure of starch components, certain specific criteria (thermal characteristics) are employed to predict the cooking and processing characteristics of rice. These parameters are reported to correlate well with the chemical composition and also with the cooking quality of rice (Pillaiyar, 1979). Water uptake capacity of rice is related to tenderness, stickiness and palatability of cooked rice. The amount of water absorbed by the rice grain at 72ºC, 77ºC and 82ºC indicate whether the variety is soft or hard for cooking. The variety which absorbed higher quantity of water at 72ºC are soft cooking type, those which absorbed maximum water at 77ºC are of intermediate type and hard cooking at 82ºC. The varieties which have the higher volume expansion ratio are of best cooking quality. Water uptake is related to palatability and cohesiveness; higher water uptake indicates good quality. Alkali spreading value test permits classification of rice into high, intermediate and low gelatinization types. In

Table 2. Grain quality characteristics of Azad Basmati (CSAR 839–3) and other basmati rice genotypes vis-à-vis minimum acceptable standards for basmati breeding

Quality Components	Minimum Acceptable Standards	Azad Basmati	Basmati 370	Type-3	Pusa Basmati-1	Improved P.B.-1	Basumathi
1. Milling Characteristics:							
Hulling (%)	> 78.0	73.53	69.57	66.43	66.00	72.03	78.37
Milling (%)	> 70.0	65.77	63.83	59.37	60.63	64.77	66.97
Head Rice (%)	> 40.0	62.67	47.33	45.07	43.07	50.07	45.70
Broken Rice (%)	-	02.07	15.40	17.47	16.67	13.77	23.73
2. Physical Characteristics:							
Test Weight (g)	-	21.33	21.57	20.17	22.13	24.63	20.57
Length (mm)	> 6.6 mm	6.28	6.61	7.28	7.31	7.31	7.04
Breadth (mm)	< 2.0 mm	1.60	1.54	1.51	1.58	1.58	1.70
L/B Ratio	> 3.0	3.93	4.29	4.82	4.63	4.63	4.14
Appearance	T&CW	T&CW	T&CW	T&CW	T&CW	T&CW	T&CW
Seed Grade	LS	LS	LS	LS	LS	LS	LS
3. Cooking Characteristics:							
WU (ml/100g)	-	860	674	799	849	949	674
VER	> 4.00	4.00	4.00	3.50	3.70	3.25	3.30
KEaR (mm)	-	12.80	12.40	12.47	14.50	11.20	14.25
KER	> 1.80	2.20	1.80	1.70	2.00	1.38	2.00
ASV	4 to 5	6.5	4.5	6.5	7.0	6.0	4.5
AC (%)	20 - 22	22.80	22.03	23.00	22.17	23.12	15.86

WU=Water Uptake, VER=Volume Expansion Ratio, KEaC=Kernel Elongation after Cooking, KER=Kernel Elongation Ratio, ASV=Alkali Spreading Value and AC= Amylose Content, LS= Long Slender, T&CW= Transluscent and Creamy White

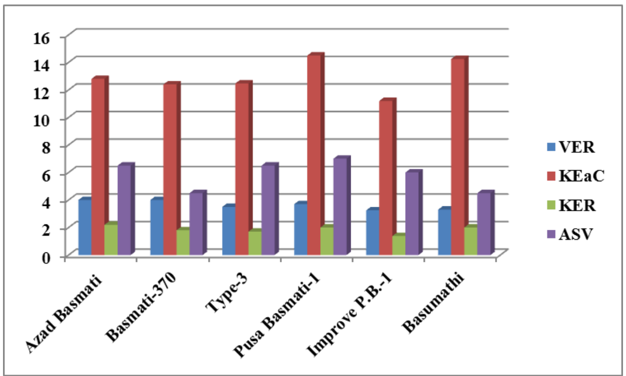

Figure 3. General and comparative presentation of cooking characteristics

the present investigation, although, the test variety Azad Basmati exhibited significantly higher water uptake (860 ml/100 g) than all the check varieties (except Improved Pusa Basmati-1), highest kernel elongation ratio on cooking but significantly higher (highest) volume expansion ratio (3.00) than all the check varieties excepting Basmati-370 because of similar value. Among check varieties, Basmati-370 and Pusa Basmati-1 proved to be the best in KER and VER, respectively on cooking, whereas improved Pusa Basmati-1, though exhibited highest water uptake, turned-out to be inferior in respect of KEaC, KER and VER in the respect of the check varieties. Sarkar *et al*., (1994) reported wide variation in KEaC for long slender rice varieties from 10.2 to 11.8mm and VER 3.7 to 4.2. It is interesting to note that the two check varieties (Basmati-370 and Basumathi) having the lowest water uptake (674 ml/100 g rice) exhibited lowest alkali spreading values (4.5) predicting medium gelatinization temperatures for the two varieties whereas the remaining varieties having significantly higher water uptake were low gelatinization temperature type (Table 1, Figure 3). Generally, breadth wise increase on cooking of rice is considered undesirable trait, while high quality rice varieties are characterized and preferred based on increase in length during cooking (Danbana *et al*., 2011). Elongation of rice can be influenced by both the l/b ratio and the amylose contents (Singh *et al*., 2005; Danbana *et al*., 2011).

Overall comparison of grain quality characteristics of the test variety Azad Basmati with five check varieties vis-à-vis minimum acceptable standards for Basmati depicted indicate (Table 2) that Azad Basmati turned-out to be the best in respect of HRR (62.67%) against a desired minimum acceptable standard of 40% for Basmati breeding (Singh, 2000); HRR for the check varieties was much lower than for Azad Basmati and ranged from 43 to 50%. All the varieties including Azad Basmati had long-slender, translucent, creamy white kernels; Grain dimensions (length, breadth, L/B ratio) of Azad Basmati were comparable to check varieties however fell marginally short in respect of grain length than the desired minimum acceptable standard of 6.6mm. All the check varieties were found to meet the desired physical standards for Basmati; Pusa Basmati-1, Improved Pusa Basmati-1 and Type-3 were the best in this respect, in that order. Although, Azad Basmati and the check varieties viz. Pusa Basmati-1 and Basumathi exhibited higher values for KER than the minimum desired values of 1.80 but Basmati-370 was similar, none of the varieties studied could match the minimum VER value of 4.00 excepting Azad basmati and but Basmati-370; Strangely, Azad Basmati having highest KER value and also exhibited the highest VER values than all check varieties excepting but Basmati-370. Check varieties Basmati-370 and Basumathi having ASV of 4.5 were adjudged to be medium-cooking type whereas Azad Basmati and the remaining check varieties were medium-cooking type. The VER, KER and ASV in all six basmati rice varieties were found very high when compared to other rice varieties ranged from 1.074 to 1.192, 0.758 to 0.987 and 3.2 to 4.3 % in VER, KER and ASV, respectively studied by Santhi and Vijayakumar (2014) in pigmented brown rice and Samal *et al.* (2014) found KLaC 5.24 to 16.45mm, KER 1.29 to 2.15 and ASV varied from 2.0 to 6.17%. Vanaja and Babu (2006) reported 1.0 to 7.0% for ASV, 1.873 to 3.17 for VER and 1.11 to 1.603 for KER in a set of 56 high yielding diverse rice genotypes. The results in this study of L/B ratio after cooking were found in the range as reported by Vanaja and Babu (2006) (1.95-3.85), Singh *et al*. (1998) (2.43- 3.98 for brown rice and 2.20- 3.65 milled rice), Singh *et al*. (2005) (2.62-4.55), Samal *et al.* (2014) 1.28 to 2.45, Khatoon and Prakash (2007) (2.21-4.12), Singh *et al*. (2002) (2.55-4.03 for raw and for parboiled 2.58-4.18) and Otegbayo *et al.* (2001) (2.12 for parboiled, 2.62 for non-parboiled white rice and 2.56 for parboiled, 2.22 for non-parboiled brown rice).

In evaluating rice grain quality, amylose content (AC) can play a significant role in determining the overall cooking, eating and pasting properties such as texture, flavor, stickiness, hardness, grain elongation, gel consistency, and gelatinization temperature of a rice variety (Pooni *et al*., 1993; Adu-Kwarteng *et al.*, 2003, Asghar *et al*., 2012). Apart from the amylose content, the rice cooking quality can also be influenced by components viz. proteins, lipids or amylopectin (Pooni *et al*., 1993; Cai *et al*., 2011). In our present study, amylose content (AC) of six basmati rice varieties showed significant variations between different rice cultivars (Table 1). It was in the range of 15-23%. This value was comparable to that found similar by the reported values of Diako *et al.* (2011a) (15.9 to 22.7%) of some new scented rice varieties, considerable with the mean values (22.91 ± 2.01%) reported in 20 newly introduced rice varieties in Ebonyi State, Nigeria by Oko *et al.* (2012) and higher than the values of Shayo *et al.* (2006) (8.25 to 19.25%). Saikia *et al.* (2012) who reported amylose content in pigmented and non pigmented aromatic rice as 2.2 to 28.8/100 g. Asaduzzaman *et al.* (2013) reported in aromatic rice cultivars of Bangladesh ranges between 14.23 to 23.01/100 g. Maisont and Narkrugsa (2009) was found that the amylose content range between 5.58-21.24%. Fari *et al*. (2011) reported AC ranged from 18.65±1.19% to 30.43±0.20% in Sri Lankan rice varieties. Lestari *et al.*, (2014) reported 18.16 to 26.51% of AC in Indonesian Indica rice varieties marginal difference with the reported values varied from 15.45 to 25.25% by Samal *et al*. (2014). The highest value of amylose content was observed in Improve P.B.-1 (23.12%) while the lowest belonged to Basumathi (15.86%). The rice varieties which had higher amylose content, required a shorter cooking time (Thomas *et al*., 2013). The Azad Basmati variety has shown high value of amylose as compared to evolved basmati varieties Basmati-370, Pusa Basmati-1 and Basumathi but found lower with Type-3 and Improve P.B.-1 when compared reported values of Thomas *et al*., (2013), it was found all basmati rice varieties were superior with a brown rice variety (3.36%) but inferior with white rice (local, medium grain type) because of it's highest AC highest (27.71%). This has been attributed to the retrogradation of the amylose molecules (Adu-Kwarteng *et al.*, 2003), which was evident and holds true with regard to the white rice variety (27.71%) as recorded in this study. These results are also on par with the observation made by Singh *et a*l. (2005). Rice varieties containing higher AC are normally more resistant to hydration (Yadav and Jindal, 2007).

Rice with low (10-20%) to intermediate (20-25%) amylose containing rice varieties have been reported to cook moist and remain soft (when cool), relatively sticky rice on cooking and is widely preferred by consumers than rice with high (20-25%) or low amylose contents (10-20%) (IRRI, 1985; Bhonsle and Sellappan, 2010). In this study, the basmati rice varieties were, thus, classified into low to intermediate amylose content rices (Juliano, 1981; Dela Cruz and Khush, 2000). All six different basmati rice varieties, including Azad Basmati were intermediate amylose varieties (20 – 25%). Basumathi rice was the only variety which fell under the low amylose content range (10 – 20%).

Conclusion

In conclusion, study showed that varietal differences were evident in physico-chemical and cooking characteristics of rice. Azad basmati exhibited high hulling (73.53%), milling (65.77%) and the highest head rice out-turn, having long-slender, translucent, creamy white kernels. On cooking Azad Basmati exhibited highest KER (2.20) and VER (3.00). Azad Basmati turned-out to be the best in respect of HRR (63%) as compared with all the check varieties (43 to 50%). All the check varieties except Basmati-370 were comparable to Azad Basmati in respect of VER. All check varieties in respect of VER, KEaC and KER were not found to be significantly better than Azad Basmati excepting Basmati-370 and Pusa Basmati-1 in respect of VER and KEaC, respectively. The amylose content of Azad Basmati variety was found higher than Basmati-370, Pusa Basmati-1 and Basumathi but shown low value as compare with Type-3 and Improve P.B.-1 basmati varieties. All basmati varieties were founded intermediate including Azad Basmati except Basumathi.

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