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Full Length Research Paper

Grain quality attributes of new Rice Basmati lines of Pakistan

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The Choice of new rice varieties by farmers and consumers at the expense of indigenous varieties have become a source of worry to scientists in Pakistan. In the present research the cooking quality and physico-chemical characteristics of 14 newly developed lines and two check varieties widely grown grown in Punjab, Pakistan were investigated. Significant variation (P<0.05) was detected among the 15 rice varieties for all the traits evaluated. The results predicted that two newly developed rice Lines showed higest cooked grain length (CGL) during cooking. The grains of PK9533-9-6-1-1 had the highest elongation ratio of 1.900. "PK 9966-10-1 has the best physical appearance in terms of length but easily dissolves in water during cooking. Most of the physico-chemical characteristic such as amylose, protein and gelatinization temperature were significantly correlated (positively or negatively) with some of the cooking quality traits i.e., elongation ratio, CGL indicating that efforts aimed at selecting rice varieties with improved cooking quality traits would warrant a consideration of the physico-chemical attributes of the rice grain. The overall cooking quality and physico-chemical attributes of some of new lines were even relatively better than the Check (Super Basmati). Farmers should, therefore, be critical in accepting new varieties that may not be comparably outstanding in yield but also in cooking quality and physico-chemical characteristics, in order to preserve the integrity of new rice varieties.

key words: Grain Length, Chalkiness, Cooking quality, Post harvest losses, Rice

INTRODUCTION

Rice (*Oryza sativa* L.) is the world's most important food crops of Asian origin and belongs to genus oryza of family graminae. Pakistan has 2846.9 thousand ha area under rice cultivation with production 6900.8 thousnad tones. Pakistan shares 21.6% in the world's rice production. It holds 4th position in rice exporting countries in the world (GOP, 2014-15). Rice remains a staple food for majority of the world's population. More than two thirds of the world relies on the nutritional benefit of rice. It is mainly used as milled or white rice produced by removing the hull and bran layers of the rough rice kernel (*paddy*) in the dehulling and milling processes, respectively. However, consumption of brown rice (hulled rice) is increasing in recent years, due to the increased

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awareness about its health benefits and good nutritional properties due higher amount of protein and minerals than white rice. Whole rice grain is composed of bran (6%-7% by weight), endosperm (≈90%) and embryo (2%-3%). Particularly rice bran constituents are proteins (11.3% - 14.9%), lipids as spherosomes (12%-18%), dietary fiber, essentials minerals, vitamins and phytochemicals: such a wide range of antioxidant phenolic compounds and γ- amino butyric acid (GABA). Starch is mostly in the endosperm of rice grain, and constitutes ~90% of milled rice on a dry weight basis (dwb); much of the starch functionality depends on two major components, amylose and amylopectin. Rice starch mainly differs in amylose content; amylose molecule determines the grain's gelatinization temperature, pasting behaviour and viscoelastic properties, and has been an important component to be considered in quality of rice. (Umadevi et al., 2012).

Rice quality has attracted significant attention and it has become the most important target in rice improvement. Evaluation of the nutritional quality of rice is mainly embodied in the detection of the content of rice starch, fat, protein, vitamins, and microelements which are beneficial to the human body. With an increasing need for field, rice harvest season and rice manufacture testing, it is necessary to study the discrimination and recognition of different varieties of rice and further to evaluate its quality control. Typically, sensory property include textural properties of cooked rice, aroma and its retention after cooking, and the ability to remain soft for several hours after cooking.

To some extent, rice sensory property especially eating quality is a subjective trait, varying with cultural, social and individual factors (González *et al*. 2004). Within countries, a range of preferences can be found. In China, sensory preference of japonica rice differs as liking softer and stickier rice whereas those of Northeast China enjoying harder and non-adhesive rice. Sensory property can be evaluated objectively by physicochemical analysis. For chemical components, amylose was formerly considered as the most important predictor of sensory quality for cooked rice (Jin *et al*. 2010). But it was found that cultivars with similar amylose contents may differ in textural properties. Recent studies showed that amylopectin structure also affects the texture of cooked rice by changing gel consistency and gelatinization temperature. For physical properties, pasting properties are co-related with some sensory attributes. However, our current knowledge of the factors affecting sensory quality is still incomplete, and more work is needed to explore physicochemical foundation of sensory properties (Fitzgerald *et al*. 2003; Bergman *et al*. 2004). Nowadays, modern analytical techniques are applied for the discrimination and identification of damaged rice plants like NIR, DNA imaging and sensing.

The quality of rice is evaluated in terms of its sensory quality, processing quality, eating quality, and nutritional quality. The assessment indexes of sensory quality of rice are mainly based on the color, appearance, smell, taste and other features which are identified by the examiner's sense organs and practical experience. It is the only cereal crop eaten mainly as whole grains and, therefore, grain quality consideration is much more important than for any other crop. The appearance of milled rice grain is an important quality attribute considered by consumers first. (Danbaba *et al*., 2012).

Thus, grain shape and size are the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production. Breeders are currently working to develop new rice varieties with improved agronomic characters to aim at giving higher grain yields. But evaluation early breeding lines for grain quality and more advanced lines for nutritional factors. Cooking and eating quality of rice have been serious problem in Pakistan, as the rice area is planted with basmati and non basmati varieties for their moistness, tenderness, gloss and taste. Recently, however, the breeding program has turned its attention to the development of long grain rice varieties, with respect to cooking and eating quality. The complex trait of rice grain quality is the sum of a number of component traits, including appearance, cooking and eating quality, and nutritional quality. (Lang et al., 2013).

Rice plays a significantly important role in people's daily life, therefore, detection of the rice quality has received progressively increasing attention. However, currently, the evaluation of rice quality lacks a uniform standard and the evaluation method depends on the test aim of the rice. Estimates of cooking quality will play an important role in exploiting further research projections of rice varieties improvement. Therefore, an attempt was made in the present studies to estimate the physical, chemical and cooking parmeters of different indigenous and new rice varieties.

MATERIALS AND METHODS

A total of 15 rice cultivars were collected from RRI, KSK from their farm sites during harvesting season.

About 500 g of grains of each line were milled with rice huller to have brown rice. The brown rice was then milled in miller machine to obtain white milled rice and bran for further analysis.

Physical Characterization

The physical properties studied were the grain size and shape, 1000-grain weight, hull % and endosperm colour. All the milled rice samples were subjected to physical characterization based on the methods reported by International Rice Research Institute (IRRI, 1980; 1996).

Average Grain Length

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. 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).

Breadth

Breadth of each grain was measured using a Vernier Caliper. The average of 10 such observations was taken for final reading of breadth of rice kernels in millimeter (mm).

L/B Ratio

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 into long slender (LS), short slender (SS), medium slender (MS), long bold (LB) and short bold (SB). (Dela-Cruz and Khush, 2000)

Cooked Grain Length

The length of 10 whole rice kernels after cooking was measured by using the micro-scale, and then average kernel length determined.

Kernal Elongation ratio (E/R)

Kernel elongation ratio was calculated by dividing the average length of cooked kernel by the average length of the raw (uncooked) rice (Juliono, 1971).

Chalkiness and kernel Color

Chalkiness was noted in the middle of rice (white center), front (white belly), or none at all.

Endosperm colour was determined by visual observation.

Hull %

Hull (%) was evaluated as difference between the milled rice weight and the paddy.

Hull % = Average weight of brown rice/ Weight of original sample

Chemical parameters

Gelatinization Temperature (GT)

This was indexed by alkali spreading test. The degree of spreading of individual milled rice kernel in a weak alkali solution at room temperature (32±2°C) was evaluated on a 7-point numerical scale. (IRRI, 1980).

Each test was conducted three times, each time, 6 intact milled grains were placed on a petri dish to which 15 ml of 1.7% KOH was added. The grains were carefully separated from each other and incubated at ambient temperature for 23 hrs to allow spreading of the grains. Grains swollen to the extent of a cottony center and a cloudy collar were given an alkali spread value (ASV) score 4 and used as check for scoring the rest of the samples in the population. Grains that were un-affected were given ASV of 1 and grains that were dispersed and disappeared completely were given a score of 7. A low ASV correspond to a high gelatinization temperature; con-versely, a high ASV indicates a low GT.

Amylose content

Amylose content (AC) of milled rice was measured by using Auto grain analyzer using the principle of NIRT.

The paddy samples 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%).

Protein content

Protein content of milled rice was measured by using Auto grain analyzer using the principle of NIRT.

Statistical Analysis

All data were analyzed by the Analysis of Variance (ANOVA) procedure using Statistixs software version 10. Differences were declared statistically sig-nificant when $P < 0.05$. Where significant differences were detected, the means were separated by the least significant difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Grain quality in rice is very difficult to define with precision as preferences for quality vary from country to country. Few people realize its complexity and various quality components involved.

The concept of quality varies according to the preparations for which grains are to be used. Although some of the quality characteristics desired by grower, miller and consumer may be the same, yet each may place different emphasis on various quality characteristics. Consumers base their concept of quality on the grain appearance, size and shape of the grain, the behaviour upon cooking, the taste, tenderness and flavour of cooked rice.

Physical characterization

The rice cooking quality characteristics evaluated included Grain lenght, grain elongation during cooking (mm), hull %, Breadth, L/B ratio, Cooked grain length, brusting %. Significant differences were observed for the tested grain quality characteristics among the 15 cultivars in this study. Significant correlations were observed among the phys-ico-chemical and grain quality attributes as shown in Table 1.

The appearance of milled rice is important to the consumer. Thus grain size and shape are the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production.

The length:breadth ratio (L/B) falling between 2.5 and 3.0 has been considered widely acceptable as long as the length is more than 6 mm. In this study L/B ratio was above than 3 for all lines including Checks which indicate attractive rice apperance. Kernel breadth ranged from 1.38mm to 1.56mm. The L/B ratio of kernel ranged from 1.7 to 4.9. According to Dela Cruz and Khus (2000) the L/B ratio decides the shape and category size of rice grain *i.e.* L/B ratio > 3.0 is for slender shape, 2.1 to 3.0 is for medium shape while = 2.0 is called as bold grain.

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. The consumer prefer rice with a translucent endosperm and pay a premium price for it, even though opacity disappears during cooking and does not alter eating quality. Preference for grain size and shape vary from one group of consumers to the other. Some ethnic groups prefer short bold grains, some have a preference for medium long grains, and long slender grains are highly prized by others. (Chueamchaitrakun et al., 2011).

Grain appearance depends upon the size and shape of the kernel, translucency and chalkiness of the grain. Rice samples with damaged eyes have poor appearance and low market value. Similarly, greater the chalkiness, lower the market acceptability. The starch granules in the chalky areas are less densely packed as compared to

Table1: Physical Parameters of new Basmati Rice Lines

S. No	Line No / variety.	Physical Parameters						
		Length (mm)	Width (Breadth) (mm)	Thickness (mm)	L/B ratio	Hull %	Grain Color	Chalkiness
	PK 10198-7-2	8.36	1.56	1.40	5.35	15.8	Off-white	None
	PK 10299-6-3	8.52	1.50	1.38	5.68	16.4	Off-white	None
	PK 10306-15-5	8.56	1.48	1.36	5.78	17.5	Off-white	None
	PK 10324-1-1	8.78	1.44	1.32	6.09	19.3	Off-white	None
	PK 9533-9-6-1-1	8.42	1.52	1.38	5.53	20.1	Off-white	None
	PK 9966-10-1	9.00	1.46	1.34	6.16	20.1	Off-white	None
	PK 9444-8-1-2	8.62	1.38	1.34	6.24	19.6	Off-white	None
	PK 9563-3-2-2-1	7.72	1.49	1.38	5.18	20.5	Off-white	None
	PK 9924-5-1-1	7.38	1.48	1.38	4.98	18.5	Off-white	None
	PK 10029-13-2-1	8.48	1.40	1.32	6.05	20.1	Off-white	None
	PK 10161-1-5-1	8.74	1.52	1.40	5.75	20.0	Off-white	None
	PK 10101	8.80	1.48	1.34	5.94	20.0	Off-white	None
	PK PB-5	8.72	1.56	1.40	5.59	19.8	Off-white	None
	PK PB-8	8.94	1.54	1.40	5.81	17.8	Off-white	None
	Super Bas. (C)	7.46	1.50	1.38	4.97	20.2	Off-white	None
	Std Error	±0.074	$\pm 8.34 \times 10^{-3}$	$\pm 4.74 \times 10^{-3}$	±0.057	±0.226		
	Mean	8.42	1.49	1.36	5.65	19.05		

translucent areas. Therefore, the chalky areas are not as hard as the translucent areas and the grains with chalkiness are more prone to breakage during milling. Chalkiness is influenced by both genetic background and the environment, as temperature immediately after flowering. Other factors such as soil fertility and water management, both of which tend to be problematic in rainfed lowlands, are expected to affect the degree of chalkiness.

"PK 9966-10-1" had the highest value for grain length (9mm) followed by "PK PB-8" (8.94mm), while "PK 9924-5-1-1" had the least (7.38mm). The range of values for grain length of check varieties varied from 7.46-8.58. The values of grain elongation during cooking among the cultivars studied ranged between 1.449-1.900 mm with a mean value of 2.04±0.76 mm. Grains of PK 9533-9-6-1-1 had the highest elongation value, followed by PK 10198-7-2, PK 10299-6-3 which is equivalent to Check. It is worthy of note that all the newly introduced lines showed insignificant result for Width, thickness, color, chalkiness among the lines and check also. During cooking rice grains absorb water and increase in length, breadth and volume. In present study the kernel length ranged from 7.38 mm to 9.00 mm. Long thin grain rice tend to break more easily during grains. (Sood, 1978; Adeyeye et al., 1995).

The grain elongation ratio is dependent on genetic factors as well as the degree of milling. 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*. (2011) 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. Rice grain length 8.31-8.65 mm and 3.00-3.04 mm breadth in pigmented brown rice was reported in previous studies. Likewise 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 was reported (Singh *et al*., 2005; Vanaja and Babu, 2006; Verma *et al*., 2013).

Table 1: Chemical Parameters of new Basmati Rice Lines

S. No	Line No / variety.	Chemical Parameters				Cooking quality Parameters		
		Moisture%	Protein %	Amylose %	ASV	CGL	Bursting	E/R
	PK 10198-7-2	11.8	6.6	24.4	5.1	15.7	3.0	1.878
	PK 10299-6-3	11.6	7.1	22.8	1.8	16.0	6.0	1.878
	PK 10306-15-5	11.7	7.1	24.9	4.8	12.4	3.0	1.449
	PK 10324-1-1	12.0	7.4	24.8	3.6	13.7	3.0	1.560
	PK 9533-9-6-1-1	12.1	6.9	24.2	5.8	16.0	2.0	1.900
	PK 9966-10-1	12.0	7.0	25.2	6.0	15.8	0.0	1.756
	PK 9444-8-1-2	11.5	7.0	23.3	5.9	13.6	0.0	1.578
	PK 9563-3-2-2-1	11.9	6.7	26.2	6.0	13.2	0.0	1.710
	PK 9924-5-1-1	11.7	7.0	26.8	6.2	13.6	2.0	1.843
	PK 10029-13-2-1	12.2	7.2	25.9	6.0	14.2	2.0	1.675
	PK 10161-1-5-1	12.1	6.6	24.0	5.5	16.2	4.0	1.854
	PK 10101	11.6	7.5	23.9	4.8	14.8	3.0	1.682
	PK PB-5	11.8	7.8	25.8	3.6	13.7	0.0	1.571
	PK PB-8	11.9	6.6	23.5	6.2	16.2	4.0	1.812
	Super Bas. (C)	12.0	7.5	24.4	2.5	13.5	2.0	1.810
	Std Error	± 0.033	±0.052	± 0.175	±0.204	±0.193	±0.227	± 0.021
	Mean	11.82	7.05	24.53	4.88	14.49	2.0	1.722

Linear elongation of rice on cooking is one of the major char-acteristics of good rice. Grain size and shape largely de-termine the market value and consumer acceptance of rice, while cooking quality is influenced by the properties of starch. Some varieties expand more in size than others upon cooking. Length-wise expansion without a corresponding increase in girth is considered a highly desirable rice grain quality trait. Grain elongation during cooking is affected by over cooking as this may lead to disintegration and curling of the cooked rice grain[18].

In such cases, under cooking could be a recommended option in order to avoid curling of the cooked rice grain. However, the correlation between amylose and water uptake ratio was surprisingly not significant. Therefore, the relationship between amylose content and water uptake ratio needs to be clarified in sub-sequent studies. It is worthy to note that high water uptake ratio affects the palatability of the cooked rice negatively.

Solids in cooking water (loss in solids) affect the stability of the cooked rice. The variation in values may be as a result of the variation in rice consistency, seen in the bursting of the grains during and after cooking, as they are of different varieties. Cooking characteristics of rice are linked to consumer preferences for rice and are very important as rice is consumed almost immediately after cooking. 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 (Cagampang *et al*., 1973; Thomas *et al*., 2013).

Water uptake capacity of rice is related to tenderness, stickiness and palatability of cooked rice.

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. Elongation of rice can be influenced by both the l/b ratio and the amylose contents (Singh *et al*., 2005; Danbaba *et al*., 2011).

Chemical parameters

The values of the chemical characteristics such as amylose, Protein and gelatinization temperature of the grain among the 16 cultivars used in this study is shown in Table 1. Highly significant variation ($p< 0.0001$) was observed among these four physico-chemical parameters. The amylose content among the varieties studied ranged between 22.3-26.8%, with a mean value of

22.91±2.01%. PK 9924-5-1-1 had the highest percentage of amylose (26.8), followed by PK 9563-3-2-2-1 (26.2) compared with Check. (Table 2). The negative value of correlation between grain elongation during cooking and amylose content, indicates that cultivars that elongate more during cooking would likely have a decreased content of amylose. Furthermore, a significant but low correlation value was obtained between optimum cooking time and gelatinization temperature.

The variation in the cooking time could be traced 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. Amylose content of milled rice has been found to be positively correlated with hardness values of cooked rice and negatively with stickiness values. Cooking quality of rice mainly depends on amylose content and gelatinization temperature. Amylose contents determine the texture of cooked rice and rice varieties with amylose content of more than 25 % absorb more water and have a fluffy texture after cooking. (Delshadian et al., 2015)

Table 1 shows the variety, the country of origin, gelatinization temperature, amylose content, and protein content. Only the pair from Pakistan differed in gelatinization temperature, which was unexpected since the standard for Basmati quality defines intermediate gelatinization temperature. Perhaps, some environmental condition during grain-filling led to the low value obtained for Basmati 385. For most pairs, there were small differences in amylose content, but in most cases, these differences did not cross the current classifications of amylose. Protein content ranged from 5.9% to 11.2% across the set. (Champagne et al., 2010).

Gelatinization temperature, is the range of temperature wherein at least 90% of the starch granules swell irreversibly in hot water with loss of crystallinity and birefringence. Although the gelatinization temperature and cooking time of milled rice are positively correlated but does not correlate with the texture of cooked rice. It is not associated with other important plant or grain traits except for certain useful correlations with amylose content Varieties with high gelatinization temperature generally have low amylose content. (Jennings et al., 1979).Many of the cooking and eating characteristics of milled rice are influenced by the ratio of two kinds of starchs; amylose and amylopectin in the rice grain. Amylose content correlates negatively with taste panel scores for cohesiveness, tenderness, color and gloss of the boiled rice. Rice varieties are grouped on the basis of their amylose content into waxy (0-2%), very low (3-9%), low (10-19%), intermediate (20-25%) and high (>25%). Intermediate amylose rices are the preferred types in most of the rice growing areas of the world, except where low-amylose japonicas are grown. Some varieties expand more in size than others upon cooking. Lengthwise expansion without increase in girth is considered a highly desirable trait in some high-quality rices. (Khush et al., 1979)

The amylose/amylopectin ratio of starch as indexed by the amylose content is the main influence of cooking and eating quality of rice. It was observed that Mahsuri Mutant had a high amylose content, whereas Basmati had a low amylose content. The amylose content of rice varieties may vary according to the temperature during the grain ripening whereby the amylose content generally decreases as the mean temperature increases. In addition to that, the amylose content of rice is also influenced by the nitrogen fertilization whereby the value decreases slightly with nitrogen fertilization but is not affected by the stage at which nitrogen is applied. (Resurrection et al. 1977). The classical relationships between the amylose (AM) content or grain dimensions and the final properties of cooked rice were not always followed. For example, rice with higher amylose and more long chain amylopectin (AP) tend to have hard cooking properties, whereas rice with lower amylose content and shorter chain amylopectin tend to have a softer texture. (González et al., 2004).

Patindol and Wang (2003) studied the physicochemical properties of three nonwaxy, long-grain rices and found that different amylopectin structures could affect rice functionality, for example, the gelatinization, retrogradation and pasting behavior. Rice with an amylose content of 7.8% in comparison with four other rice varieties with 15.6–18.9% amylose content. Furthermore, starch retrogradation encompassed the changes that occur in gelatinized starch from an initially amorphous to a more ordered state. High-GT starch had higher values for enthalpy and percentage of retrogradation than low-GT starch. (Bao *et al.*, 2000).

The higher amylose content in rice grain produces a harder texture and less gloss in the cooked rice. The very low amylose content of each cultivar gave different eating quality characteristics to the processed rice products and has been used for food ingredients, such as stabilizing sauces, gravies and puddings, to resist water separation during freeze-thaw cycles (Sattari *et al.*, 2015).

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).

The gelatinization temperature is one of the important indicators of the cooking quality of cooked rice. The heat energy required to completely gelatinize starch in rice or flour is critical to the food processor who must optimize the heat input, cooking time and temperature. A higher gelatinization temperature requires longer time to cook. Environmental conditions include temperature during grain development, especially starch production influence the gelatinization temperature. A high ambient temperature during grain ripening result in starch with a higher gelatinization temperature. (Henrita et al., 2015. Singh at al., 2013).

Rice storage proteins are composed of albumin, globulin, prolamin, and glutelin, and make up most of the total proteins in rice. Glutelin makes up about 80%, albumin 1～5%, globulin 4～15%, and prolamin 2～8% of total protein. However, the relative quantities of each protein fraction are affected by cultivation conditions, genotypes, and the analytical methods employed. There was a considerable variation in total protein content in selected 16 lines /cultivars. Total protein content in brown rice of the cultivars ranged from 6.6 to 7.8% with an average of 8.8%, as predicted by which is about 37% higher than that of the non-waxy cultivar. (Bao *et al.,* 2000)

The gelatinization temperature of rice starch is defined as the temperature at which nearly all the starch granules in a sample lose their birefringence. Gelatinization temperature can be grouped as low (<70 ℃), intermediate (70–74 ℃) and high (>74 ℃). There is some evidence that the degree of starch crystallinity, the molecular size, the degree of branching of amylopectin fraction and the diffraction intensity of the amylose in rice may have relation to its gelatinization (Juliano 1972; Kim et al., 2013).

The second major component of rice is protein. The protein content of milled rice is relatively low and significantly influenced by variety, environment, crop, season and nitrogen fertilization. The nutritional quality of rice depends on the protein content which is the second major component of grain next to starch. The protein is a key factor influencing the eating quality of rice. Rice contributes 24.1% of dietary protein out of 207.9 grams of rice consumed per day per person.

The rice protein is superior because of its unique composition of essential amino acids. Studies on protein content in different Pakistani varieties reported a range of 7.38 to 8.13% protein content. These levels of proteins in rice are very essential as proteins form the basic building blocks for cells and tissue repairs in the body. Protein content for all the rice varieties evaluated ranged between 5.9 to 11.0 Usually, the average value of total crude protein content is taken as 7.00 % in rice seed. In another study, similar range of 6.7 to 11% protein in brown rice in 74 varieties from India. Some varieties from Himachal Pradesh, India were reported to have 6.61 to 7.28% total crude protein (Sing *et al.*, 1998).

Indigenous cultivars of the north eastern hill states of India possess high protein content with a range of 6.14 to 12.07%. Padmavathi *et al.* (2015) reported 6 to 12.6 % crude protein content in three hundred improved rice varieties in India. Even a wide range of 6.56 to 12.86 % protein content was reported in 40 rice varieties grown in Kashmir. Crude protein content of nine aromatic rice cultivars ranged from 9.17 to 11.77 %. The protein in a local rice cultivar from Manipur was reported as high as 12.07%. The variation in protein content observed between brown and white rice is because of bran portion, which is higher in protein and significantly increase the protein content of brown rice as reported earlier (Anjum *et al.* 2007).

The main storage protein in rice is oryzenin. Like in other cereals, prolamins, globulins and albumins also occur. Oryzenin is composed of subunits that are linked by both intra- and inter-molecular disulphide bridges.

During storage of rice, the molecular weight of oryzenin increases significantly, which correlates with an increase in disulphide bonding. The decrease in solubility is thought to explain the decrease in stickiness observed in stored rice. Since proteins impact so much on the end-use of other cereals, it is most likely that they contribute to the quality of cooked rice. Therefore, it is important to be able to measure the contribution of proteins to rice quality, and by doing so, we increase our ability to improve the quality of rice. (Fitzgerald 2006; Saikia *et al.* 2012) who reported amylose content in pigmented and non pigmented aromatic rice as 2.2 to 28.8/100g. Asaduzzaman *et al.* (2013) reported in aromatic rice cultivars of Bangladesh ranges between 14.23 to 23.01/100g. Lestari *et al*., (2014) reported 18.16 to 26.51% of AC in Indonesian Indica rice varieties. 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 (Verma et al., 2015)

The quantity and type of protein are important factors in rice nutrition. Various factor affect protein content of rice: climate and environment, kind and quantity of fertilizer applied, duration of maturity, degree of milling, and varietal characteristics. The protein content of rice varieties ranged from 5.46 to 9.07 % and remains relatively unchanged during the first 3 months after storage (Table 2). Indica rice genotypes offered higher protein content than the others. On the other hand, rice varieties derived from crossing show intermediate values for protein content. Thus, large variations in protein content exist among rice cultivars due to genetic and environmental factors as depicted by Gayin et al., (2009).

CONCLUSION

In the present study, physical, chemical and cooking characteristics were evaluated among 14 newly developed lines along with 2 checks. Some of the rice varieties exhibit their high grain quality properties when compared with check. They can be used in rice breeding programs for further improvement purposes.

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