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Evaluation of grain quality traits in popular rice varieties of Andhra Pradesh

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Abstract
Twenty popular rice varieties, including sixteen released and four pre-released varieties obtained from *Kharif* 2019, were screened for quality parameters such as physical, chemical, cooking traits. Correlation coefficients were evaluated to identify rice varieties with desirable grain quality. All the 14 traits evaluated have shown significant variance. 1000 kernel weight has positive significant association with kernel length (r = 0.843) and kernel breadth (r = 0.724). Kernel length after cooking with elongation ratio (r = 0.059), alkali spreading value with water uptake (r = 0.137), percent hulling with percent milling (r = 0.49), and head rice recovery(r = 0.140) also has depicted positive correlation which specifies that these are the principle attributes to enhance grain quality of rice. Significant Correlation among quality characters might help breeders emphasize better grain quality and rice consumers to identify rice variety with desirable grain quality.

Keywords: Rice, grain quality, physicochemical, cooking traits, correlation

Introduction
Rice is the third-largest food crop in the world, only after wheat and corn. Rice localized ascertain lately appeared as an essential topic for improving human health utilizing food security, safety and standard quality assurance (Chung *et al.* 2017) [12].
Across the world, rice exists in many combinations of length-width ratio, grain weight, bran color, and endosperm chemical characteristics. End-use quality characteristics desired in some areas of the world can be entirely unacceptable to other regions. Many local rice varieties do not enter the export market other than being used close to where it is produced (Bergman, 2019) [6].
Inherent quality traits/characteristics rule rice grain quality. These quality traits are controlled by rice genotype, environmental components, and traditional practices (Kale *et al.*, 2017) [25].
As consumer choices in Asia and throughout the globe are different due to varied demographics and culture, defining uniform attributes to capture regional grain quality options has become challenging. Therefore, the new proxy tests need to identify rice grain quality to match the requirements of end-user choices of released varieties in the market (Butardo *et al.*, 2018) [8]. Consumer susceptibility and market liability towards rice are dependent on various quality characteristics of grain, such as physical, chemical, cooking, and eating quality attributes or nutritional parameters (Thilakarathna *et al.*, 2017) [60].

Material and Methods
The experiment material was constituted with 20 popular rice varieties (16 released and 4 pre released varieties) which were collected from Regional Agricultural Research Station (RARS), Maruteru, and West Godavari District. The salient features of varieties are mentioned here under (Table 1)

Methods
Quality analysis
After harvesting, threshing and cleaning, the seeds from individual genotypes were dried under shade until moisture content reaches to 14%. The seed was dehusked in a Satake laboratory huller (Type THU 35 A) and polished in a Satake Rice Polisher (Type TM 05). The polished seed (10%) obtained was then utilized for the analysis of 14 seed quality traits namely hulling (%), milling (%), head rice recovery (%), kernel length and breadth (mm), length/breadth ratio (L/B), 1000-grain weight (g) (physical quality traits); kernel length after cooking (KLAC)

(mm), kernel elongation ratio (ER), volume expansion ratio (VER) and water uptake (cooking quality traits); amylose content (%), gel consistency (mm), alkali spreading value (chemical quality traits) at Quality Laboratory, Regional Agricultural Research Station (RARS), Maruteru. Milling percentage was calculated by dividing the weight of milled rice by weight of paddy. The HRR percentage and broken rice were calculated using the standard formula of (weight of milled rice/weight of grain) x 100 (Cruz and Khush, 2000) [14]. Twenty grains at random from each sample from each replication were dehusked by hand and the length and breadth in milli meters was recorded using Dial micro meter. 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) (Ramaiah, 1985) [42]. Kernel elongation ratio (ER) was calculated by dividing the average length of cooked kernel by the average length of the raw rice (Murthy, 1965) [35]. KLAC was measured by the method of Juliano *et al.* (1966) [24]. ASV was estimated by the method advocated by Little *et al.* (1958) [31]. The simplified procedure suggested by Jennings *et al.* (1979) [23] was used for estimating the AC and gel consistency.

Table 1: List of Rice Varieties

Released varieties		
S. No	**Name of the variety**	**Grin type**
1	Amara (MTU1064)	MS
2	Badava Mahsuri (PLA 1100)	MS
3	Bhadavapuri Sannalu (BPT 2270)	MS
4	Chandra (MTU 1153)	LS
5	Cottondora Sannalu (MTU 1010)	LS
6	Indra (MTU1061)	MS
7	Ksheera (MTU 1172)	MS
8	Nellore Mahsuri (NLR34449)	MS
9	Pushyami (MTU1075)	LS
10	Samba Mahsuri (BPT 5204)	MS
11	Sri Druthi (MTU 1121)	MS
12	Srikakulam Sannalu (RGL 2537)	LB
13	Swarna (MTU 7029)	MS
14	Tarangini (MTU 1156)	LB
15	Varam (MTU 1190)	MS
16	Vijetha (MTU 1001)	MS
Prereleased varieties		
S. No	**Name of the variety**	**Grain type**
1	MTU 1210	MS
2	MTU 1224	MS
3	MTU 1239	MS
4	MTU 1262	MS

Results and discussion

Table 2: Mean performances of rice varieties for quality traits

S. No	**Physico-chemical characteristics**	**Statistical parameters**				
		Mean	**CV**	**S.E**	**Range lowest**	**Range Highest**
Physical traits						
1	Hulling (%)	79.57	3.30	0.59	75.33	85.0
2	Milling (%)	69.03	3.76	0.58	62	72.67
3	HRR (%)	62.28	4.24	0.59	59	67.33
4	KL (mm)	5.65	9.29	0.12	4.62	6.48
5	KB (mm)	2.03	10.83	0.05	1.65	2.39
6	L/B	2.93	5.51	0.04	2.69	3.24
7	1000 g wt (g)	19.11	16.88	0.72	14.03	24.07
Chemical traits						
1	ASV	4.61	26.88	0.28	2.6	7.0
2	AC (%)	23.24	3.72	0.19	21.7	24.73
3	GC (mm)	52.57	22	2.59	37.67	75
Cooking traits						
1	VER	4.25	7.88	0.08	3.45	4.79
2	WU (ml)	197.67	21.35	9.44	92	258
3	KLAC (mm)	7.60	18.52	0.32	5.62	10.89
4	ER	1.68	5.16	0.02	1.5	1.84

The data on grain quality and its components of 20 (16 released and four pre-released) rice varieties were collected during *Kharif* 2019. Mean values of 14 quality traits recorded are furnished in **Table 2** and are described as character-wise. For most of the characters, a vast difference was observed among varieties.

Physical quality traits

Hulling (%)

The hulling percent among the 20 varieties ranged from 75.33% to 85%, with a general mean of 79.57%. Swarna recorded the highest hulling recovery at 85%, followed by Badava Mahsuri with 82.33%. The lower hulling percent of 75.33 has occurred in Pushyami following Sri Druthi with 75.67% of hulling.

High hulling percent resulted in high head rice recovery of 93.3% in parboiled rice with the higher (5.5 x 104 N/m2) process steam pressure (Igbeka *et al.*, 2008) [22]. Rita and Sarawgi (2008) [44] has specified more than 80% of hulling is desirable, and if the hulling percent increases, the head rice recovery increased as well (Swamy and Bhattacharya, 2009) [57].

Milling (%)

The overall mean of percentage of milling was 69.03%. The milling percent was higher in Bhavapuri Sannalu (72.67%), followed by Chandra (72%) and Tarangini (71.67%). The lowest milling percent of 62% was obtained in the pre-released variety MTU 1262, following Ksheera with 66%.

A study by Binodh *et al*. (2006) evaluated milling percent for fifty-five promising rice cultural varieties and hybrids from Tamil Nadu that ranged from 49.20 to 89.50 percent.

Cultivar differences can govern milling percent, climatic conditions during grain maturation and harvest moisture content, etc. (Thompson *et al*., 2006, Siebenmorgen et al., 2007; Salassi *et al.*, 2013, Sahu *et al.* (2017) [62, 53, 48, 46].

Head rice recovery (HRR) (%)

Head rice recovery range varied from 59% to 67.33%. The mean value, in general, was 62.28%. Sri Druthi inscribed the highest recovery percent among the varieties (67.33%) studied, followed by pre-released variety MTU 1210 (65.67%), whereas the lowest head rice recovery was displayed in Pushyami (59%) followed by Varam (59.33%), Nellore Mahsuri, Samba Mahsuri and MTU 1239 with 59.67%.

Head rice recovery percent is considered an inherent trait even though environmental components such as temperature and humidity, grain size, shape, hardness, moisture content, harvest and storage conditions, processing, and type of mills directly affect it. Dipti *et al., (*2002) [19] and Rani *et al*., (2006) [43]. Verma *et al*. (2012) [66] described more remarkable head rice recovery with minimum breakage within a range of 47-55 percent in bold and short grains. The values for Head rice recovery varied from 49.48 (*Ezhome*-2) to 57.45 (*Vyttila*-8),which was noticed in newly released bold and medium rice grain varieties in the report given by Puri *et al*., 2014 [41]. During milling, low-quality milled rice recovery occurs due to elevated breakage caused by low surface hardness. Head rice recovery percent of 62.16 and 33.66 were seen in raw and parboiled rice varieties of Jyothi, respectively (Lakshmi, 2011; Sathyan, 2012) [30].

According to Dhankar's (2014) [17] study, more significant head rice recovery is 84 percent of complete milled rice or paddy weight of 58 percent under well-managed circumstances. On an average, Head rice recovery of 55 percent was noted in commercial rice mills, although rice mills used in villages show 30 percent of head rice recovery. The noticeable difference in head rice percent can be due to the variation in milling conditions.

Kernel length (KL) (mm)

The mean values obtained for kernel length ranged from 4.62 mm to 6.48 mm with a grand mean of 5.65 mm. The higher kernel length was registered by all long slender variety namely Tarangini (6.48 mm) followed by long bold variety Srikakulam Sannalu (6.45 mm). The lowest kernel length was observed in Samba Mahsuri (4.62mm), followed by pre-released variety MTU 1224 (4.92 mm).Chukwuemeka *et al.* (2015) [13] reported that the length of 9 rice varieties grown and processed in Ebonyl state was ranged from 6.31 to 7.63 mm, and average width ranged from 2.04 to 2.28mm, and there is significant variance within the varieties ($P< 0.05$). Geetanjali *et al.* 2019 and Dipti *et al.* (2002) [19] classified grains lengths greater than 6mm as long, 5mm - 6mm medium, and less than 5mm as short.

Kernel breadth (KB) (mm)

Kernel breadth ranged from1.65 mm to 2.39 mm with a mean value of 2.03 mm. The kernel breadth of Vijetha was the highest (2.39 mm), followed by MTU1239 (pre-released variety) (2.34 mm), and the lowest kernel breadth was noticed in MTU 1224 (pre-released variety) (1.65mm), followed by Nellore Masuria (1.74 mm), Samba Mahsuri (1.74 mm).

Kernel L/B ratio

The observed mean for kernel L/B was 2.93. It ranged from 2.69 to 3.24. All long, slender, and long bold varieties recorded L/B ratio of greater than 3.00. Srikakulam Sannalu, a long, bold type, has an L/B ratio of 3.24, which is greater than all lengthy-slender varieties followed by Indra (3.19). It was the lowest in medium-slender varieties such as Swarna (2.69). The kernel L/B ratio (2.45) of 32 rice varieties reported by Dhurai *et al.* (2014) [18] was found to be similar to our study.

1000 grain weight (g)

Grain weight has a significant influence on grain yield, cooking characteristics and sensory qualities of rice. According to the study of Kwarteng *et al*. (2003) [29], a thousand-grain weight ranging from 20 to 30 g is desirable in rice. In the present study, mean of 1000 grain weight, in general, was 19.11 g while it ranged from 14.03 g to 24.07g. The desirable varieties with high 1000 grain weight are Cottondora Sannalu, Chandra, and Pushyami, which registered a mean weight of 24.07g, 23.83g, and 22.83g, respectively. The lowest 1000 grain weight is found in MTU 1262 (pre-released variety) (14.03 g), followed by Samba Mahsuri (14.27 g).

The results are in consent with the studies of Ozguven and Kubilay (2004) [38] and Varnamkhasti *et al*. (2008) [65]. The 1000 kernel weights in the above-given studies have ranged between 18.81 to 22.92 g in brown rice. They also have stated that, while processing from rough to brown rice, the 1000kernel weight decreased. Another study by Meena *et al.* (2010) [33] specified that the 1000 grain weight ranged between 11.36 and 20.18 g in brown rice. Saini *et al*. (2013) [47] described 1000 grain weights of 22.52g, 22.77 g, 23.19 g, 22.60 g, 22.78 g, 22.76 g, 22.61 g, 22.55 g, 23.09 g, 21.37 g, and 22.76 g in the rice varieties of Jayathi, Onam, Tulasi, Parambuvattan, Thekkancheera, Mancumpu 519, Annapoorna, Thottacheera, Karuthadukkan, Chomala, and Mo-7 respectively.

Many of the intermediate amylose containing rice varieties had a higher thousand-grain weight. Following this, Thomas *et al.* (2013) [61] determined highest thousand kernel weight (19.43 g) was obtained in glutinous rice accompanied by Bario rice (19.23 g) and brown rice (18.66 g), respectively. The lowest grain weight was seen in the white rice variety (16.97 g).

Chemical quality characters

Amylose (%)

Amylose determines the starch content of rice, and this influences the physical appearance after cooking. The amylose content observed over the varieties ranged from 21.70 to 24.73 percent. In our study, all the varieties (released and pre-released) have intermediate content of amylose. A significant difference in the percentage of grain amylose content was among the varieties studied by Abeysekera *et al*. (2016) [1]. Shahidullah *et al.* (2009) [51] stated that amylose content in all rice grades ranged between 20.7 - 21.4%. Low amylose content generates cooked rice to become moist and sticky. Amylose and amylopectin content of grains determines cooked rice texture, and consumers prefer intermediate amylose content rice varieties.

Gel consistency (GC) (mm)

The affinity of cooked rice to harden on cooling was calculated by gel consistency. The gel consistency is related to the eating quality of rice. The harder the rice higher the gel consistency (Kanlayakrit and Maweang, 2013) [26]. The gel consistency (GC) was categorized into soft, medium, and challenging. The range of GC was 37.67 – 75 mm. This trait ranged from 37.67 (hard gel) to 75 (soft gel) with a mean value of 52.57. Bhavapuri Sannalu (75mm) depicted the greater gel consistency, which, when cooked the rice, tend to be soft on cooling. Ksheera (37.67 mm) has shown the lowest

gel consistency, followed by Varam (38.33) and Vijetha (40 mm).
All the pre-released rice varieties were classified as a medium gel containing (41-60mm) varieties, and eight released varieties, Cottondora Sannalu (48.33mm), Indra (58.33mm), Nellore Mahsuri (55.67mm), Samba Mahsuri (48mm), Sri Druthi (43mm), Srikakulam Sannalu (56mm), Swarna, Vijetha were classified as medium gel consistency varieties

Alkali spreading value (ASV)
The range of alkali spreading value was low, intermediate, and high amid all rice varieties. The mean, in general, was 4.61 with a range of 2.6 to 7. Highest ASV was observed in Bhavapuri Sannalu (7), followed by Vijetha (6.13), and the least value is manifested in Nellore Mahsuri (2.6). The intermediate alkali spreading value specifies the medium disintegration and categorized as intermediate GT, which is most desirable for quality grain (Madhubabu *et al.* 2017 and Bansal *et al.,* 2006) [32, 4].

Cooking quality characters
Kernel length after cooking (KLAC) (mm)
The mean value was 7.60 mm, with a range of 5.62 mm to 10.89 mm. The highest mean was recorded in Srikakulam Sannalu (10.89 mm), followed by Samba Mahsuri (9.33 mm). The shortest kernel length after cooking was observed in Varam (6.83 mm).
If rice elongates lengthwise, it gives a more acceptable appearance, and if it expands girth-wise, it gives a coarse look. Rice that has high cooked grain length with a more satisfactory appearance is mostly the preferred one (Pathak *et al.* 2016) [39].

Volume expansion ratio (VER)
Volume expansion was contemplated to be a principal character while determining the quality of cooked rice grains. After cooking higher volume expansion ratio was considered a desirable feature preferred by consumers. Highest VER was seen in Bhavapuri Sannalu (4.79), followed by Samba Mahsuri (4.65) and Swarna (4.54). The lowest ratio has acquired in Tarangini (3.45), followed by Ksheera (3.72). The overall mean for volume expansion ratio was 4.25. VER has ranged from 3.45-4.79.
Results of volume expansion ratio are in support with the study of Nirmala Devi *et al.* (2015) [37] however, on the contrary to this, it was described that the consumers well accept lower VER than higher VER and higher elongation ratio (ER) of the cooked rice is preferred than lower ER (Shahidullah *et al.,* 2009) [51].

Kernel elongation ratio (ER)
The values of kernel elongation ratio range were from 1.5 to 1.84, with the general mean of 1.68. Samba Mahsuri (1.84) showed the highest elongation ratio, followed by Bhavapuri Sannalu (1.78).
Pre- released variety MTU 1262 displayed the lowest elongation ratio (1.5). Mean values of elongation ratio in our study are similar to the study of Sahu *et al.* (2017) [46], where the elongation ratio is 1.45 among Chhattisgarh's indigenous rice varieties.

Water uptake (WU) (ml)
Hydration characteristics of rice are measured by water uptake, which may be governed by gelatinization temperature and kernel porosity. The highest value of 258 ml was observed in Vijetha, while the smallest amount of 92 ml was found in Varam. The mean of the trait was 197.67 ml, with a range of 92 ml to 258 ml. The appearance of cooked rice is linked with the quantity of water uptake during the cooking process. (Tan *et al.,* 2000).The findings of our study resembled the reports given by Devi *et al.* (2016) [16].
The majority of the physical and chemical characters such as amylose, GC, and GT were significantly associated with the cooking quality traits such as elongation during cooking, optimum cooking time, suggesting that attempts directed to select rice varieties with enhanced cooking quality attributes can assure the thought of considering the physicochemical quality traits of the rice varieties Pramila *et al.* (2011) [40].

Table 3: Analysis of variance for quality traits

PHYSICAL TRAITS					
Source	**SS**	**df**	**MSS**	**F**	**P-Value**
Variety	35933.79	19	1891.25	2255.28	<0.05
Physical traits	355618.03	6	59269.67	70677.93	<0.05
Variety * Physical traits	37154.84	114	325.92	388.65	<0.05
Error	234.80	280	0.84		
Corrected Total	428941.46	419			
CHEMICAL TRAITS					
Source	**SS**	**Df**	**MSS**	**F**	**P-Value**
Variety	2603.28	19	137.01	32.56	<0.05
Chemical traits	70142.46	2	35071.23	8334.97	<0.05
Variety * Chemical traits	5156.68	38	135.70	32.25	<0.05
Error	504.93	120	4.21		
Corrected Total	78407.34	179			
COOKING TRAITS					
Source	**SS**	**Df**	**MSS**	**F**	**P-value**
Variety	25444.971	19	1339.209	52.349	<0.05
Cooking traits	1680028.787	3	560009.596	21890.66	<0.05
Variety * Cooking traits	76164.674	57	1336.222	52.233	<0.05
Error	4093.139	160	25.582		
Corrected Total	1785731.571	239			

Analysis of Variance
Analysis of variance was carried out for 14-grain quality traits, namely physical quality traits: hulling (%), milling (%), head rice recovery (%), kernel length and breadth (mm), length/breadth ratio (L/B), 1000 grain weight (g); cooking quality characters: kernel length after cooking (KLAC) (mm), kernel elongation ratio (ER), volume expansion ratio (VER) and water uptake (WU); chemical quality attributes: amylose content (%), gel consistency (mm), alkali spreading value (Table 3) Mean sum of squares are furnished in Table 2. The mean sum of the varieties' squares has statistically displayed significant differences (p = <0.005) for all 14 quality traits. This suggests that variability exists largely due to various sources of materials of the genetically diverse varieties. This indicates that the selection of desirable lines from the existing gene pool for quality attributes have enough scope. The occurrence of wide variance can be attributed to various treatments taken and environmental influence affecting the phenotypes.

Table 4: Correlation coefficients for 14 Quality characters among rice

	Hulling (%)	Milling (%)	HRR (%)	1000g. wt (g)	KL (mm)	KB (mm)	L/B	AC (%)	GC (mm)	ASV	KLAC (mm)	ER	VER	WU (ml)
Hulling (%)	1	0.4902*	0.1401*	-0.0042	-0.1730	0.0412	-0.2572	0.1097	0.1773	-0.0423	-0.2462	0.3190	0.0674	0.0823
Milling (%)		1	0.2564	0.1032	0.21232	0.0624	0.1825	0.1435	0.3002	0.1394	0.2772	0.1590	0.3342	-0.2111
HRR (%)			1	-0.0487	-0.1138	-0.0091	-0.1439*	0.0551	0.0154	0.1991	0.2374	0.2512	-0.1541	0.1790
1000 g. wt (g)				1	0.8432**	0.7242**	0.2824	-0.1233	0.0214	-0.0413	-0.3011	-0.2262	-0.2560	0.0724
KL (mm)					1	-0.653*	0.5521*	0.0282	0.0562	0.0288*	0.0684	-0.3073	-0.2992	0.0442
KB (mm)						1	-0.2792*	0.0232	-0.0922	-0.1366	-0.2871	-0.1520	-0.3454	-0.2623
L/B							1	0.0111	0.1484	-0.2014	0.3940	-0.2412	-0.0011	-0.1991
AC (%)								1	0.3926	-0.2290	0.4902*	0.4242	0.0932	0.0642
GC (mm)									1	-0.3384	0.0751	-0.0941	0.2364	-0.0682
ASV										1	0.1512	-0.1252	0.0785	0.1376*
KLAC (mm)											1	0.0593*	0.3871	0.1388*
ER												1	0.3790	-0.2542
VER													1	-0.2993
WU (ml)														1

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed)
HRR- head rice recovery, KL- kernel length, KB- kernel breadth, L/B- kernel l/b ratio, AC- amylose, GC- gel consistency, ASV- alkali spreading value, KLAC- kernel length after cooking, ER- elongation ratio, VER- volume expansion ratio, WU- water uptake

Correlation coefficients for 14 Quality characters among rice

The character hulling percent has significant, positive correlation with per cent milling (r = 0.490) and head rice recovery (r = 0.140). 1000 kernel weight has a positive significant association with quality features such as kernel length (r = 0.843) and kernel breadth KB (0.724). Head rice recovery revealed negative but non-significant correlations with kernel dimensions like kernel length(r = - 0.013) and L/B ratio (- 0.143). Head rice recovery was positively correlated with ASV (r = 0.199) and Amylose content (r = 0.055) but was non-significant. Negative significance of kernel breadth was observed with L/B ratio, (r = -0.279), Water Uptake (r = -0.061) and alkali spreading value (r = -0.136). Kernel length after cooking has positive significant association with elongation ratio (r = 0.059). ASV displayed positive significant relation with water uptake (r = 0.137) and kernel length (r = 0.028) and negative non-significant correlation with gel consistency (r = -0.338) while volume expansion ratio have no significant association with any of the quality traits. Gel consistency has a positive, non-significant correlation with amylose (r=0.392) as a shown in Table 4.

A positive and significant relationship of percent hulling with percent milling and head rice recovery revealed that the varieties having higher percentage of hulling also have the highest values for milled rice and head rice. Results related to the current study were familiar with the reports of Singh *et al.* (2020) [54], Nirmala Devi *et al.* (2015) [37], Nayak *et al.* (2003) [36], Tejpal (1987) [59], Chauhan *et al.* (1995) [9], and Sarkar *et al.*, (1994) [49].The study on four local varieties in India by Basri et al. (2015) [5] also shows a positive association between grain weight and length. A study on aromatic fine grain rice by Mia et al. (2012) [34] indicated that the increase in grain weight occurs with increased kernel length, supporting the present study. Similarly, kernel length KL has a positive relation with kernel breadth (r = 0.653) and L/B ratio (r = 0.552), which means 1000 kernel weight of rice varieties has a strong positive association with kernel length and breadth, which means that the more refined the grain weight, slender and more elongate the grain as reported by Girma *et al.*, 2016[20]. HRR showed a non-significant, negative association with grain L/B ratio. These findings happened to be in concurrence with the reports given by Gopalakrishnan *et al.* (1982) [21], Tejpal (1987) [59], and Shivani (2007) [52]. There is a constant abrasion among the kernels during polishing, and thus lengthy slender grain varieties are susceptible to more breakage than that of short, bold grain. Kernel length has a significant negative association with kernel breadth, which reveals that grain length and slenderness are inherited separately, prompting long slender grain types. Positive significant association of alkali spreading value with water uptake suggests that varieties with greater water uptake have low gelatinization temperature (GT), which is in accord with the reports earlier given by Shivani *et al.* (2007) [52], Tomar and Nanda (1982, 1987) [63, 64], Chauhan *et al.*, (1995) [9], Choi *et al.* (1999) [10]. The kernel breadth revealed a significant negative association with the L/B ratio. A similar association was reported by Khatun *et al.* (2003) [27], Sood and Siddiq (1980) [55], Deosarkar and Nerkar (1994) [15], and Christopher *et al.* (1999) [11]. Positive and non-significant correlation between gel consistency and amylose specifies that higher amylose content may guide the selection of varieties with soft gel consistency. This is also reported by Shivani *et al*. 2007 [52].

A comparative study of correlations between physical, chemical, and cooking quality traits was carried out. The significant correlations acquired in the current research were discussed below.

Percent Hulling, Milling, and HRR are principle quality attributes for rice that emphasize the variety's commercial attainment. Positive significant correlation coefficients were found between physical quality traits such as hulling percent with percent milling and head rice recovery. One trait can simultaneously improve three quality traits: percent hulling, milling, and head rice recovery, *i.e.*, either hulling percent or milling percent or head rice recovery.

As far as cooking quality traits are concerned, kernel length after cooking is regarded as the principal trait. Lengthwise enlargement after cooking was considered a desirable characteristic in high-quality rice such as India's basmati rice. It fetches the maximum premium because linear elongation gives an excellent shape to the rice. Grain shape and visual appearance of rice before and after cooking are crucial to determining acceptance of a rice variety. Prime rice-eating nations incline varieties that elongate considerably after cooking. In the present study, kernel length after cooking and kernel elongation ratio are interdependent, as indicated by the significant positive association. The selection of either characteristic will ultimately raise the mean value of the interdependent trait.

Physical quality trait, namely L/B ratio, has a positive and significant association with cooking quality, namely kernel length after cooking. L/B ratio is a good indicator of kernel length after cooking. Thus higher the L/B ratio, the more will be the kernel length after cooking. Selecting any of these traits will elevate the overall quality trait.

The amylose content is a chemical quality attribute that has an effect on the texture of cooked rice. Intermediate amylose content, a soft gel containing rice variety were preferred by most of the customers. Amylose content of the genotypes has a significant positive correlation with cooking property KLAC which is supported by the study of Rithesh *et al.* (2018) [45]. Amylose content is widely accepted and is a significant determinant of the cooking and eating quality of rice. Positive and non-significant Correlation between the two chemical quality traits, namely gel consistency and amylose content, was considered standard. Thus it showed that selecting desirable intermediate values of gel consistency leads to automatic selection of a desirable level of amylose content. The association of the two physical quality traits, namely head rice recovery and l/b ratio, displayed a non-significant negative Correlation as expected. Selection of the above-referred traits will improve quality in rice breeding programs. This is also reported by Shivani *et al.* (2007) [52] and Khatun *et al.* (2003) [27].

According to Ahmed *et al.* (2020) [2], the variance specifies the occurrence of a substantial amount of difference, possibly due to the diverse source of materials that the genotypes were genetically divergent. This presents enough scope for opting varieties from the current gene pool for good quality and composition aspects. Significant enhancement of primary quality attributes like percent hulling, milling, and head rice recovery, amylose content, gel consistency, and kernel elongation ratio can be made by exploring rice varieties by presenting the materials to the rice breeders for utilization of rice varieties in future breeding programs (Sahu *et al.* 2017) [46].

Conclusion

Rice varieties such as Chandra, Bhavapuri Sannalu, Indra, Swarna, and Samba Mahsuri among the released varieties and MTU 1210, MTU 1224 among the pre-released varieties recorded high percent hulling, milling, and head rice recovery with intermediate amylose, alkali spreading value, soft gel and higher volume expansion ratio and minimum elongation ratio which can be preferable traits for rice consumers counting for rice with the best quality.

References

1. Abeysekera WKSM, Premakumara GAS, Bentota AP, Abeysiriwardena DS de Z. Grain Amylose Content and its Stability over Seasons in a Selected Set of Rice Varieties Grown in Sri Lanka. The Journal of Agricultural Sciences 2016;12:43-50. http://dx.doi.org/10.4038/jas.v12i1.8205.
2. Ahmed A, Bilal M, Jabbar S, Mumtaz A, Khalid N, Asghar M, *et al.* Physicochemical and Sensory Evaluation of Indigenous Rice Genotypes. Journal of Agriculture Research. 2020;58(2):89-96.
3. Ashraf H, Murtaza I, Nazir N, Wani AB, Naqash S, Husaini AM. Nutritional profiling of pigmented and scented rice genotypes of Kashmir Himalayas, Journal of Pharmacognosy and Phytochemistry 2017;6(6):910-916.
4. Bansal UK, Kaur H, Saini RG. Donors for quality characteristics in aromatic rice. Oryza 2006;43(3):197-202.
5. Basri F, Sharma HP, Jain P, Mohato G. Grain quality and starch evaluation of local varieties of rice (*Oryza Sativa* L.) growing in Jarkahand state, India. International Journal of Current Research 2015;7(1):11895-11900.
6. Bergman CJ. Rice end-use quality analysis, AACCI published by Elsevier inc.in cooperation with AACC international 2019. https://doi.org/10.1016/B978-0-12-811508-4.00009-5
7. Bhattacharya KR. Physicochemical basis of eating quality of rice 2009. Doi: 10.1094/CFW-54-1-0018.
8. Butardo Jr. VM, Sreenivasulu N, Juliano BO. Improving Rice Grain Quality: State-of-the-Art and Future Prospects, Rice Grain Quality: Methods and Protocols 2018. https://doi.org/10.1007/978-1-4939-8914-0_2.
9. Chauhan JS, Chauhan VS, Lodh SB. Comparative analysis of variability and correlation between quality components in traditional rainfed upland and low land rice. Indian Journal of Genetics 1995;55:6-12.
10. Choi H, Cho J, Chi SY. Varietal difference in water absorption characteristics of milled rice and its relation to the other grain quality components. Korean Journal of Crop Science 1999;44:288-295.
11. Christopher A, Jebaraj S, Backiyarani S. Interrelationship and path analysis of certain cooking quality characters in heterogenousnous populations of rice (*Oryza Sativa* L). Madras Agriculture Journal 1999;86:187-191.
12. Chung IM, Kim JK, Lee KJ, Park SK, Lee JH, Son NY, *et al*. Geographic authentication of Asian rice (*Oryza sativa* L.) using multi-elemental and stable isotopic data combined with multivariate analysis, Food Chemistry 2017;240:840-849, DOI:10.1016/j.foodchem.2017.08.023.
13. Chukwuemeka AI, Kelechi AJ, Bernard A. Cooking And Physicochemical Properties Of Five Rice Varieties Produced In Ohaukwu Local Government Area. European Journal of Food Science and Technology 2015;3(1):1-10
14. Cruz ND, Khush GS. Rice grain quality evaluation procedures. In: R.K. Singh, U.S. Singh and G.S. Khush, eds., Aromatic rice. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, Calcutta 2000, pp. 15-28.
15. Deosarkar DH, Nerkar YS. Correlation and path analysis for grain quality characters in Indica rice. Journal of Maharastra Agricultural University 1994;19:175-177.
16. Devi KR, Parimala K, Venkana V, Lingaiah N, Hari Y, Satish Chandra B, *et al*. Estimation of variability for grain yield and quality traits in rice (*Oryza sativa* L.). International journal of pure applied bioscience 2016;4(2):250-255.
17. Dhankhar P. Rice Milling. International Organisation of Science Reseach Journal of Engineering 2014;5(4):34-42.
18. Dhurai SY, Bhati PK, Saroj SK. Studies on genetic variability for yield and quality characters in rice (*Oryza sativa* L.) under irrigated fertilizer management. The Bioscan 2014;9:745-748.
19. Dipti SS, Bari MN, Kabir KA. Grain quality characteristics of some Beruin rice varieties of Bangladesh. Pakistan Journal of Nutrition 2003;2(4):242-245.
20. Girma BT, Mohammed H, Abegaz K. Physical characteristics and nutritional quality of salt tolerant rice

genotypes. Journal of Cereals and Oilseeds 2016;7(2):7-13. July 2016 DOI: 10.5897/JCO2016.0149.
21. Gopalakrishna G, Agarwal RL, Mani SC. Effects of dates of harvesting on milling of rice. Oryza. 1982;19:217-218.
22. Igbeka RJC, Gbabo A, Dauda SM. Effect of variety, pressure and specific volume of steam on the head rice yield of milled parboiled rice**.** Journal of food science and technology 2008;45(3):282-283.
23. Jennings PR, Coffman WR, Kauffman MHE. Grain quality: Rice improvement. International Rice Research Institute, Philippines Chapter 1979;6:101-120.
24. Juliano BO, Onate LU, Imundo AM. Relation of starch composition, protein content and gelatinization to cooking and eating quality of milled rice. Food Technology 1966;19:1006-1011.
25. Kale SJ, Jha SK, Prerna Nath. Effects of variable steaming on chemical composition, starch characteristics, and glycemic index of basmati (Pusa Basmati 1121) rice, Journal of Food processing and Engineering 2017. https://doi.org/10.1111/jfpe.12567.
26. Kanlayakrit W, Maweang M. Postharvest of paddy and milled rice affected physicochemical properties using different storage conditions. International Food Research Journal 2013;20(3):1359-1366.
27. Khatun MM, Hazrat-Ali M, Quirio D, Cruz ND. Correlation studies on grain physicochemical characteristics of aromatic rice. Pakistan Journal of Biological Science 2003;6(5):511-513.
28. Kurniawan RT, Conrado D, Nikolaos T, Lina T, Felichi MA, Cheryl A, *et al*. Biofortified indica rice attains iron and zinc nutrition dietary targets in the field, Scientific Reports 2015;6:19792. www.nature.com/scientificreports, DOI: 10.1038/srep19792.
29. Kwarteng EA, Ellis WO, Oduro I, Manful JT. Rice grain quality: a comparison of local varieties with new varieties under study in Ghana. Food Control 2003;14(7):507-514.
30. Lakshmi AS. Quality evaluation of parboiled rice and its products from germinated rice. *M. Sc. (Home Science) thesis*, Kerala Agricultural University, Thrissur 2011, 84p.
31. Little RR, Hilder GB, Dawson EH. Differential effect of dilute alkali on 25 varieties of milled white rice. Cereal Chemistry 1958;35:111-126.
32. Madhubabu P, Suman K, Rathod RR, Abdul-Fiyaz D, Sanjeeva Rao, Sudhakar P, *et al*. Evaluation of Grain Yield, Quality and Nutrients Content in Four Rice (*Oryza sativa* L.) Genotypes. Current Journal of Applied Science and Technology 2017;22(1):1-12.
33. Meena SK, Vijayalakshmi D, Ravindra U. Physical and cooking characteristics of selected aromatic rice varieties. Journal of Dairy Foods and Home Science 2010;29(3-4):227-231.
34. Mia AB, Das MR, Kamurzzaman M, Talukder NM. Biochemical traits and phyico-chemical attributes of aromatic fine rice in relation to yield potential. American Journal of Plant Science 2012;3:1788-1795.
35. Murthy PSN. Genetic studies in rice (*Oryza sativa* L.) with special reference to contain quality features- *M.Sc. (Botany) thesis*, Orissa University of Agriculture & Technology, Bhubaneswar 1965, p 68.
36. Nayak AR, Chaudhary D, Reddy JN. Genetic variability and correlation study among quality characters in scented rice. Agricultural Science Digest 2003;23(3):175-178.
37. Nirmaladevi G, Padmavathi G, Kota S, Babu VR. Genetic variability, heritability and correlation coefficients of grain quality characters in rice (*oryza sativa* L.). Sabrao journal of breeding and genetics 2015;47(4):424-433.
38. Ozguven F, Kubilay V. Some physical, mechanical and aerodynamic properties of pine (*Pinus pinea*) nuts. Journal of Food Engineering 2004;68(2):191-196.
39. Pathak K, Rathi S, Sarma RN, Baishya S. Assessment of physical, chemical and antioxidant properties of few pigmented glutinous rice grown in Northeast India, Indian Journal of Plant Physiology. July–September 2016;21(3):287-299. DOI 10.1007/s40502-016-0237-0.
40. Pramila CK, Rame-Gowda, Sharanappa, Pavithra-Vani BV, Ramachandra R. Genotypic variation for milling, cooking and nutrient quality as influenced by methods of production in rice. Research Journal Agrilculture Science 2011;2(3):468-473.
41. Puri S, Dhillon B, Sodhi SN. Effect of degree of milling on overall quality of rice - a review. International Journal of Advanced Biotechnology and Research. 2014;5(3):474-489.
42. Ramaiah K. Grain Classification Page No. 629 - Rice Research in India, ICAR Publication 1985.
43. Rani NS, Manish K, Pandey GS, Prasad V, Sudharshan I. Historical significance, grain quality features and precision breeding for improvement of export quality Basmati varieties in India. Indian Journal of Crop Science 2006;1(1-2):29-41.
44. Rita B, Sarawgi AK. Agro-morphological and quality characterization of Badshah bhog group from aromatic rice germplasm of Chhattisgarh. Bangladesh Journal of Agriculture Research 2008;33:479-492.
45. Rithesh BN, Ramchander S, Rajeswari S, Uma D, Robin S, Jeyaprakash P, *et al*. Characterization of Physio-Chemical Properties of Starch among Traditional and Commercial Varieties of Rice (*Oryza sativa* L.) using Rapid Visco Analyser. International Journal of Current Microbiology and Appiled Science 2018;7(10):1490-1503, https://doi.org/10.20546/ijcmas.2018.710.167.
46. Sahu PK, Sharma D, Mondal S, Kumar V, Singh S, Baghel S, *et al*. Genetic Variability For Grain Quality Traits In Indigenous Rice Landraces Of Chhattisgarh. India, Journal of Experimental Biology and Agricultural Sciences 2017;5(4), DOI: http://dx.doi.org/10.18006/2017. 5(4).439.455.
47. Saini P, Francies RM, Joseph J, Bastian D, Vigneshwaran V. Genetic assessment of core set developed from short duration rice accessions held by Kerala Agricultural University. Journal of Tropical Agriculture 2013;51(1-2):126-131.
48. Salassi ME, Deliberto MA, Linscombe SD, Wilson CE, Walker TW, McCauley GN, *et al*. Impact of Harvest Lodging on Rough Rice Milling Yield and Market Price. Agronomy Journal 2013;105(6):1860. doi:10.2134/agronj2013.0238.
49. Sarkar RK, Nanda BB, Dash AB, Lodh SB. Grain characteristics and cooking quality of aromatic and non-aromatic long and slender varieties of rice (*Oryza Sativa* L). Indian Journal of Agriculture Science 1994;64:305-309.
50. Sathyan NT. Quality evaluation of germinated rice and rice products. M. Sc. (Home Science) thesis, Kerala Agricultural University, Thrissur 2012, 97p.

51. Shahidullah SM, Hanafi MM, Ashrafuzzaman M, Ismail MR, Khair A. Genetic diversity in grain quality and nutrition of aromatic rices. African Journal of Biotechnology 2009;8(7):1238-1246.
52. Shivani D, Viraktamath BC, Rani N Shobha. Correlation among various grain quality characteristics in rice. ORYZA- An International Journal on Rice 2007;44(3):212-215.
53. Siebenmorgen TJ, Grigg BC, Lannin SB. Impacts of Preharvest Factors During Kernel Development on Rice Quality and Functionality. Annual Review of Food Science and Technology 2013;4(1):101-115.
54. Singh KS, Suneetha Y, Kumar VG, Rao VS, Raja DS, Srinivas T, *et al*. Variability, correlation and path studies in coloured rice. International Journal of Chemical Studies 2020;8(4):2138-2144. P-ISSN: 2349–8528.
55. Sood BC, Siddiq EA. Studies on component quality attributes of basmati rice. (*Oryza sativa* L.). Z. Pflanzenzuchtg 1980;84:294-301.
56. Sperotto RA, Ricachenevsy FK, Waldow V, Fett JP. Iron Biofortification in rice: It's a long way to the top. Plant Science 2012;190:24-39.
57. Swamy BPM. Genome wide mapping of quantitative trait loci (QTLs) for yield and grain quality traits in O. sativa cv Swarna x O. nivara backcross population. *Ph. D Thesis*, Osmania University, Hyderabad, India 2009.
58. Tan YF, Xing YZ, Li JX, Yu SB, Xu CG, Zhang Q, *et al*. Genetic bases of appearance quality of rice grains in Shanyou 63 an elite rice hybrid. Theoretical and Applied Genetics 2000;101:823-829.
59. Tejpal. Genotype variability for grain quality characteristics. MSc Thesis. IARI, New Delhi, India 1987.
60. Thilakarathnaa GC, Navarathne SB, Wickramasinghe I. Identification of Important Physical Properties and Amylose Content in Commercially Available Improved and Traditional Rice Varieties in Sri Lanka, International Journal of Advanced Engineering Research and Science (IJAERS) 2017;4(12). https://dx.doi.org/10.22161/ijaers.
61. Thomas R, Wan-Nadiah WA, Bhat R. Physiochemical properties, proximate composition, and cooking qualities of locally grown and imported rice varieties marketed in Penang, Malaysia. International Food Research Journal. 2013;20(3):1345-1351.
62. Thompson JF, Mutters RG. Effect of weather and rice moisture at harvest on milling quality of california medium-grain rice. Transactions of the ASABE 2006;49(2):435-440. doi:10.13031/2013.20392.
63. Tomar JB, Nanda JS. Correlations between quality traits in rice. Oryza 1982;19:13-16.
64. Tomar JB, Nanda JS. Genetics and correlation studies of gel consistency in rice. Cereal Research Communications 1987;15(1):13-20.
65. Varnamkhasti MG, Mobli H, Jafari A, Keyhani AR, Soltanabadi MH, Rafiee S, *et al*. Some physical properties of rough rice (*Oryza sativa* L.) grain. Journal of Cereal Science 2008;47(3):496-501.
66. Verma DK, Mohan M, Yadav VK, Asthir B, Soni SK. Inquisition of some physico-chemical characteristics of newly evolved basmati rice. Environment and Ecology 2012;30(1):114-117.