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Physicochemical and Cooking Quality of Rice Genotypes

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Abstract

Even though rice production is expanding in Ethiopia, very little information is available on the grain quality of rice. The objective of this study was, therefore, to determine the physicochemical and cooking qualities of rice genotypes. The physicochemical analysis of 15 rice genotypes conducted at the food and nutrition Laboratory of Bahirdar University showed that most of the genotypes had high to intermediate amylose content, which showed the susceptibility of the genotypes for stickiness. The cooking time of the 15 rice genotypes ranged from 12 to 30 minutes and the loss of solid during cooking was from 1.94 to 5.31%. Nonsignificant (P < 0.05) difference was found in grain elongation in most of the genotypes. Optimum cooking time was positively correlated with the water uptake ratio, alkali spread value and ash content. This shows that the presence of minerals elongate the cooking period. Gel consistency had positively correlated with alkali spread value but it had negatively correlated to ash, water uptake ratio and optimum cooking time. Generally, it was found that some genotypes had favorable grain quality and good correlation with most important characteristics. Even though good cooking characteristics were found in some of the genotypes, it is highly recommended to characterize more genotypes and improve important cooking quality traits of rice in Ethiopia.

Keywords: Amylose content, cooking quality, gelatinization, genotype, rice characterization

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1. Introduction

Rice is an important grain with regard to human nutrition and caloric intake. Rice varieties have various morphological, physicochemical and cooking properties. Quality of rice may be considered from the viewpoint of size, shape and appearance of the grain, milling quality, cooking properties and nutritional contents (Bhonsle and Sellappan, 2010).

Most of the cooking and eating characteristics of rice are influenced by the ratio of the two kinds of starches: amylose and amylopectin in the rice grain (Sanjiva *et al.*, 1952). According to the classification of Kumar and Khush (1986), rice varieties are grouped into higher (> 25%),intermediate (20 – 25%) and low (< 20%) amylose content groups. The gel consistency is a measure of the tendency of cooked rice to be soft. Rice grains are classified into soft, medium, and hard based on the length of the gel (IRRI, 2015). Gelatinization temperature determines the time required for rice grain to completely gelatinous. Varieties with low to intermediate gelatinization temperature are favored for the reason of their softness after cooking. According to the procedure of Little *et al.* (1958), the gelatinization temperature is indirectly determined by disintegration of rice grain in KOH solution which is called alkali spread value.Aordingly, rice grains are classified as high (1-3), intermediate (3-5) or low (6-7) gelatinization.

Cooking time determines stickiness and tenderness of rice grain (Anonymous, 1997), mostly it differs from 15 to 25 minutes in studied varieties (Danaba *et al*., 2011; Dipti *et al*., 2002, 2003). In terms of fuel and energy consumption, rice with lower cooking time is favored (Danbaba *et al*., 2011).

Kernel elongation has been found to be one of the important parameters for evaluation of rice quality. It ranges from 1 to 1.6 mm of traditional varieties and 1 to 1.1 mm of high yielding varieties (Bhonsle and Sellappan, 2010). Rice grains with higher elongation ratio and lower volume expansion are preferred quality because increase in length gives a finer appearance while girth expansion gives a coarse appearance (Shahidullah *et al*., 2009). In addition, water uptake ratio and solid gruel loss are important to determine the volume of expansion, water absorption and the amount of solid loss of rice grain during and after cooking.

Although rice is produced in some parts of Ethiopia, research on rice in the country mainly targeted in searching for high yielding varieties. The study of grain quality of rice varieties was very limited in Ethiopia, so the present study will benefit rice producers, breeders and consumers in providing evidence on cooking and related properties of rice genotypes cultivated in the country. Therefore, this experiment had been conducted with the aim of determining the physicochemical and cooking qualities of different rice genotypes and to identify their relations.

2. Materials and Methods

The present study was conducted at the food and nutrition laboratory of the Bahirdar University from July to August, 2015. The grain samples were collected from Werer Agricultural Research Center (WARC). The tested genotypes are listed below (Table 1).

Table 1. Designation, pedigree and origin of the tested rice genotypes

Entry	Designation	Pedigree	Origin
1	AT 401	-	SRI LANNKA
2	IR 29	IR 833-6-2-1-1/O.NIVARA	IRRI
3	IR 55179-3B-11-3	IR4630-22-2-5-1-3/N.BOKRA	IRRI
4	IR 59418-B-P-2-2	IR10198-66-2/AT 401	IRRI
5	IR 66946-3R-178-1-1	IR29/POKKALI B	IRRI
6	IR 70023-4B-R-R-12-3-1-1	IR20184-3B-8-2B-1/IR10198-66-2	IRRI
7	IR 71829-3R-10-3	IR20/IR55182-3B-14-3-2	IRRI
8	IR 71829-3R-89-1-1	IR20/IR55182-3B-14-3-2	IRRI
9	IR 71907-3R-2-1-1	IR33731-1-1-4-3-2-2/IR52713-2B-8-2B-1-2	IRRI
10	IR 71907-3R-2-1-2	IR63731-1-1-4-3-2-2/IR52713-2B-8-2B-1-2	IRRI
11	IR 71991-3R-2-6-1	IR5/IR52713-2B-8-2B-1-2	IRRI
12	IR 72048-B-R-16-2-3-3	IR55182-3B-14-3-2*2/IR44699-26-3-1-1	IRRI
13	IR 72593-B-18-2-2-2	IR65195-3B-13-2-3//IR24/IR24	IRRI
14	IR 73055-8-1-1-3-1	IR71656-5R-B-12PB/IR60494-2B-18-3-2-3	IRRI
15	NERICA4	CG14/WAB56	WARDA

IRRI, International Rice Research Institute; WARDA, West Africa Rice Development Association

2.1 Preparation of Samples These genotypes were collected from IRRI for field evaluation under irrigated condition. They were evaluated for the last two years in the lowland part of the country (Werer, Afar Region) and showed promising performance for irrigated production. After storage in an air conditioned room (Temperature 16^{0}C) for almost one year 1kg of each sample was prepared for grain quality evaluation. Three different samples were taken for each genotype for every parameters and treated in the CRD (Completely Randomized Design) in three replications.

2.2 Physiochemical Analysis

Gel consistency was determined based on the consistency of milled rice paste that has been gelatinized by boiling with dilute alkali and cooled to room temperature. Tubes were laid horizontally and total length of the gel measured in millimeters (Little *et al*., 1958). The rice samples are classified as hard (26–40 mm), medium (41–60 mm) or soft (61–100 mm). For determination of the water uptake ratio, 2 g sample of rice was taken to a small beaker and it was cooked with 20 ml of water for 5 minutes under pressure. After cooling, the water uptake ratio was determined by taking decanted unabsorbed water and by calculating the water taken with rice in ml. It was expressed as a gram of water used/ gram of rice (Chagampang *et al.,* 1973). Alkali spreading value was estimated according to the procedure reported by Biswas and Juliano (1988). Three intact milled grains from each sample were soaked and placed uniformly in a petri dish, which contained 5 mL of 1.7% potassium hydroxide solution (KOH). The Petri dish is roofed, undistributed and kept at 30°C for 23 hours in an incubator. The spreading of each grain is rated visually on 7-point numerical scale given as follows 1: grain not affected; 2: grain swollen; 3: grain swollen, collar incomplete and narrow; 4: grain swollen, collar complete and wide; 5: grain split or segmented, collar complete and wide; 6: grain dispersed, merging with collar and 7: grain completely dispersed and intermingled (Biswas and Juliano, 1988).

2.2 Proximate Composition Analysis

Total amylose content was determined using calorimetry method with iodine (Chrastil, 1987). One (1.0) g of finely ground dried sample was weighed and incinerated at 600 ^{0}C for 6 hours in a muffle furnace until ash was obtained for ash content determination. The ash was cooled in a desiccator and reweighed (AOAC, 2000). The ash content (%) of the rice sample was calculated as % ash = weight of the ash / weight of the original sample (1g) x 100.

2.3 Cooking Characteristics

The amount of solid gruel loss, head rice samples (2g) in 20 ml distilled water was cooked for minimum cooking time. The gruel was transferred on several washings and made to volume with distilled water. The aliquot having leached solid, evaporated at 110^{O}C in an oven until completely dried. The solid was weighed and percent gruel solid was reported (AACC, 2009). To determine optimum cooking time head rice (2 g) samples were taken in a test tube from each variety and cooked in 20 ml distilled water in a boiling water bath. The optimum cooking time was determined by removing a few kernels at one minute time interval starting from the 10th minute during cooking and pressing them between two glass plates until no white core is left (AACC, 2009). Elongation ratio was calculated by dividing cumulative ratio of the length of 10 cooked rice kernels by the length of 10 uncooked kernels (AACC, 2009).

2.4 Data Analysis

The data were taken three times (replications) for each genotype from the same sample. It was subjected to analysis of variance (ANOVA) of completely randomized design (CRD) using the GLM procedure of SAS (statistical analysis system) version 9.0 (SAS, 2002). Comparison of treatment means was made using least significant difference (LSD) test at the 5% level of probability. Simple linear correlation analysis was done to investigate the interrelation of physicochemical, proximate and cooking characteristics.

3. Results and Discussion

3.1 Physiochemical Characteristics

The gel consistency of IR 29, IR 55179 and IR 72593 were significantly ($P < 0.05$) the lowest, whereas the gel length was higher ($P < 0.05$) in IR 70023, AT 401, IR 71901, IR 71889 and IR 73055 (Table 2).

Table 2. Physicochemical characteristics of grains from 15 rice genotypes

	Physicochemical characteristics				
	GL	**WUR**	**GC**	**ASV**	**Gelatinization**
Genotype	**Mm**	**%**			
AT 401	38.33^{jk}	1.85^{f}	Hard	2.33^{hi}	High
IR 29	54.00^{a}	1.65^{i}	Medium	7.00^{a}	Low
IR 55179	52.00^{b}	1.50^{j}	Medium	6.67^{ab}	Low
IR 59418	39.67^{hi}	2.25^{a}	Hard	4.67^{de}	Intermediate
IR 66946	42.33^{g}	2.15^{b}	Medium	3.00^{gh}	High
IR 70023	37.33^{k}	2.09^{c}	Hard	1.00^{j}	High
IR 71810	40.67^{h}	1.85^{f}	Medium	4.00^{ef}	Intermediate
IR 71889	39.00^{ij}	2.25^{a}	Hard	3.00^{gh}	High
IR 71901	39.00^{ij}	1.89^{e}	Hard	2.00^{i}	High
IR 71902	46.67^{d}	1.99^{d}	Medium	4.67^{de}	Intermediate
IR 71991	45.33^{e}	1.89^{e}	Medium	4.00^{ef}	Intermediate
IR 72048	43.67^{f}	1.75^{g}	Medium	5.33^{cd}	Intermediate
IR 72593	51.67^{b}	1.69^{h}	Medium	6.00^{bc}	Low
IR 73055	39.33^{ij}	1.85^{f}	Hard	1.67^{i}	High
NERICA4	48.67^{c}	1.65^{i}	Medium	4.67^{de}	Intermediate
Mean	**43.83**	**1.89**		**4.00**	
LSD	**1.02**	**0.03**		**0.70**	

Where; GL, gel length; WUR, water uptake ratio; GC,= gel consistency; ASV: alkali spread value; i.e. Characteristics at each column designated by the same latter are not significantly different at P<0.05.

The gel length was relatively medium in IR 66946, IR 72048 and IR 71991. In this experiment with the exception of few genotypes (AT 401, IR 59418 and IR 70023) most of the genotypes had medium gel constancy which tends to remain softer after cooling. The water uptake ratio ranged from 1.49 (IR 55179) to 2.25 (IR 59418). IR 59418, IR 71889, IR 66946 and IR 70023 had significantly higher water uptake ratio. Whereas, IR 55179, IR 29 and NERICA 4 had significantly ($P < 0.05$) lower water uptake.

The rice grains are classified based on gel length as soft (61 to 100 mm), medium (41 to 60mm) and hard (27 to 40 mm) (IRRI, 2015). According to the report of Juliano (1985) on factors contributing to nutritional property of rice protein, most consumers prefer softer than hard gel consistency. The low values of gel consistency are associated with high protein content, which is attributed to the hard gel consistency (Juliano, 1985). Grain with hard gel consistency has a fluffy texture (Basri *et al.*, 2015). The hard gel consistency implies longer cooking time. When cooked, rice with hard gel consistency hardens faster than those with a soft gel consistency. Rice with soft gel consistency are cooked more tenderly and it remain soft even upon cooling (Oko *et al.*, 2011).

Generally, in this experiment with the exception of few genotypes (AT 401, IR 59418 and IR 70023) most of the genotypes had medium gel constancy which tended to remain softer after cooling.

3.2 Proximate Analysis

The amylose content was significantly ($P < 0.05$) higher in IR 29 followed by IR 55179 which can be classified under high amylose group, and significantly lower in IR 71991, AT 401, IR 73055 and IR 71901 (Table 3). The genotypes with intermediate amylose content were IR 72593 and NERICA 4. In reverse IR 70023, AT 401, IR 73055 and IR 71901 had significantly higher ($P < 0.05$) amylopectin content, whereas IR 29 and IR 55179 were found with lower amylopectin. IR 70023, AT 401, IR 71901 and IR 73055 were found with the significantly higher ash content while IR 29, IR 55179, IR 71902 and NERICA 4 had signed ($P < 0.05$) small amount of ash (Table 3).

Table 3. Starch and ash proximate analysis of fifteen rice genotypes

	Proximate Analysis			
	Ash	**AMY**	**AMP**	**AC**
Genotype	**(%)**	**(%)**	**(%)**	
IR 55179	0.69^{l}	25.79^{b}	74.21^{k}	High
IR 29	0.65^{m}	27.14^{a}	72.86^{l}	High
NERICA4	0.76^{j}	20.18^{d}	79.82^{i}	Intermediate
IR 72593	0.79^{i}	22.72^{c}	77.28^{j}	Intermediate
IR 66946	0.82^{h}	10.38^{j}	89.62^{c}	Low
IR 71889	0.90^{e}	11.22^{i}	88.78^{d}	Low
IR 71810	0.88^{f}	13.73^{h}	86.26^{e}	Low
IR 71991	0.90^{e}	14.43^{g}	85.57^{f}	Low
IR 59418	0.91^{d}	17.48^{f}	82.52^{g}	Low
IR 71902	0.72^{k}	18.05^{ef}	81.95^{gh}	Low
IR 72048	0.85^{g}	18.45^{e}	81.55^{h}	Low
IR 73055	0.93^{c}	8.42^{k}	91.58^{b}	Low
IR 70023	0.97^{a}	5.96^{l}	94.04^{a}	Very Low
AT 401	0.94^{b}	8.32^{k}	91.68^{b}	Very Low
IR 71901	0.93^{c}	8.73^{k}	91.27^{b}	Very Low
Mean	0.84	15.40	84.60	
LSD	0.01	0.03	0.2	

Where; AC, amylose content type; AMY, amylose content; AMP, amylopectin content; i.e., characteristics of each column designated by the same letter are not significantly different P < 0.05l.

The amount of water uptake during cooking is associated with the appearance of cooked rice (Tan *et al*., 2000). The higher the imbibition ratio of rice, the lower will be the energy content per unit volume or weight of cooked rice as they will have more water and less solid material (Dipti *et al.*, 2002). IR 59418, IR 71889, IR 66946 and IR 70023 had significantly higher water uptake ratio indicating lower energy content and higher economic value because of the high increase in volume during cooking (Danbaba *et al.*, 2011). They will take more energy to cook due to the high amount of amylose (Frei and Becker, 2003). Amylose content might be responsible for high water uptake ratio. As Frei and Becker (2003) reported, rice with high amylose content tends to absorb more water upon cooking. The high water uptake ratio negatively affects the palatability of the cooked rice (Oko *et al.*, 2012). Congnizant to this fact, genotypes with medium amylose content (NERICA 4 and IR 72593) could be useful in their optimum moisture absorption, energy content and palatability.

Ash content is an indicator of mineral content in rice grain (Oko and Ugwu, 2011). IR 70023, AT 401, IR 71901 and IR 73055 were found with significantly higher ash content. High ash content in milled rice is an indication of good quality minerals in the food (Dipti *et al.*, 2003). It may affect the sensory quality of rice, especially color and taste (Shayo *et al.*, 2006).

3.3 Cooking Characteristics

The gruel loss was significantly ($P < 0.05$) minimal for IR 59418, IR 70023 and IR 72593. The gruel loss was significantly higher ($P < 0.05$) in IR 29 and AT 401 (Table 4). For all the genotypes it ranged from 1.94 to 5.31%. The range of optimum cooking time of the 15 genotypes ranged from 12 to 34 minutes (Table 4). This is a very wide range where some take very short time and others takes very long cooking time. The genotypes IR 29, IR 72593 and IR 55179 took significantly shorter cooking time while IR 70023, AT 401 and IR 71901 took significantly ($P < 0.05$) longer cooking time.

Table 4. The average cooking time, solid gruel loss and elongation ratio of fifteen rice genotypes

	Cooking Characteristics		
	OCT	**SGL**	**ER**
Genotype	**Min**	**%**	
AT 401	30.33^{b}	5.05^{a}	1.15^{abc}
IR 29*	12.00^{j}	5.31^{a}	1.13^{bc}
IR 55179	18.33^{h}	4.01^{bc}	1.04^{d}
IR 59418	25.67^{e}	1.94^{f}	1.13^{bc}
IR 66946**	28.33^{c}	4.19^{b}	1.18^{ab}
IR 70023	34.67^{a}	2.01^{f}	1.03^{d}
IR 71810	27.33^{d}	4.04^{bc}	1.20^{ab}
IR 71889	28.67^{c}	3.28^{e}	1.21^{a}
IR 71901	30.33^{b}	3.44^{de}	1.10^{cd}
IR 71902	25.67^{e}	3.74^{cd}	1.13^{bc}
IR 71991	28.33^{c}	3.40^{de}	1.15^{abc}
IR 72048	20.33^{g}	4.04^{bc}	1.10^{cd}
IR 72593	15.33^{i}	2.34^{f}	1.17^{abc}
IR 73055	29.00^{c}	4.10^{bc}	1.18^{ab}
NERICA4	24.33^{f}	4.08^{bc}	1.17^{abc}
Mean	25.24	3.66	1.14
LSD	0.24	0.71	0.62

Where OCT, optimum cooking time; SGL, solid gruel loss; ER, elongation ratio; characteristics at each column designated by the same letter are not significantly different P<0.05.

Most of the genotypes were not significantly different in elongation ratio, but it was relatively higher in IR 71889 and IR 71810; and lower in IR 70023 and IR 55179 (Table 3).

Gelatinization temperature was used to group rice genotypes into high (> 74^{o}C, ASV 1-3), intermediate (70-74^{o}C, ASV 3-6) and Low (< 70^{o}C, ASV 6-7) (Cruz and Kush, 2000). As the alkali spread value indicated, the gelatinization of six genotypes, including the released variety (NERICA 4) was intermediate gelatinization temperature (70-74^{o}C) which shows the softness of these genotypes after cooking. The other six rice genotypes had a high gelatinization temperature (> 74^{o}C) that clearly indicted their hard chewing property. The remaining genotypes namely IR 29, IR 55179 and IR 72593 had low gelatinization (< 70^{o}C). The later genotypes need short time for cooking and they became sticky after cooking and they had intermediate gel consistency. Low,intermediate and high gelatinization in rice grains have been reported by different researchers (Ravi *et al.*, 2012; Danaba *et al.*, 2011; Diako *et al.*, 2011; Bhonsle and Sellappan, 2010; Dipti *et al.*, 2002) on different rice varieties. The experiment by Shayo *et al*. (2007) pointed out that high gelatinization temperature increases the cooking time that may affect the taste and aroma of rice due to the loss of volatile compounds that contribute to flavor and aroma.

Most of the cooking and eating characteristics of rice are influenced by the ratio of (amylose and amylopectin) of starch in the rice grain (Danbaba *et al*., 2011). Ashgar *et al.* (2012) and Dipti *et al*. (2002) observed that rice with high amylose content show high volume expansion during cooking and cook dry, less tender and become harder upon cooling, while low amylose varieties cook moist and sticky.

Rice are grouped based on their amylose content into waxy (0 – 2%), very low (3-9%), low (< 20%) intermediate (20-25%) and high (>25%) amylose (Cruz and Khush, 2000). Intermediate amylose contents in rice varieties are preferred in most of the rice growing areas of the world as cooked rice in such a situation becomes soft (Rao *et al.*, 2013). The study of Juliano and Villarreal (1993) on different rice varieties from different countries in Africa, Asia and Europe also showed that intermediate amylose content was preferred by most consumers across the three continents. According to Leloup *et al.* (1991) when the ratio of amylose and amylopectin exceeds 2.5, it can have a strong influence on swelling index. This study shows that two genotypes (IR 55179 and IR 29) had nearly 2.5 ratio of amylose and amylopectin which showed the flexibility of most of the genotypes but as the swelling increases the gruel loss becomes higher (Danbaba *et al*., 2011).

The gruel loss indicates the amount of solid dissolved from rice grain during cooking (Ravi *et al.*, 2011). For all the genotypes it ranged from 1.94 to 5.31%, which is smaller than the study of Ravi *et al.* (2011) on *Salem samaba* variety (7%). The less amount of gruel loss in the studied genotypes may relate to their salt tolerance characteristics. These genotypes can be cooked without burning because of their minimum loss of solid gruel during cooking (Danbaba *et al*., 2011). This is the additional merits of the studied genotypes..

The result of cooking time somehow agrees with the result of Danbaba *et al*. (2011) who found the difference in optimum cooking time of excess water between 15 to 25 minutes on *Offada* rice varieties. The shorter the cooking time is better in terms of fuel and energy consumption during cooking (Danbaba *et al*., 2011).

Elongation ratio is the measure of increase in length and breadth of rice after cooking (Ravi *et al.*, 2012). Generally, most of the genotypes were not significantly different, but elongation ratio was relatively higher in IR 71889 and IR 71810. Grain elongation on cooking is dependent on genetic factors as well as the degree of milling (Diako *et al.*, 2011). Bhonsle and Sellappan (2010) indicated that lengthwise elongation was more preferred because it gives the finer appearance, but girth wise elongation gives a coarser appearance.

3.4 Correlation among Studied Traits

Ash content showed significant correlation with most of the parameters and it is positively correlated with amylopectin (r = 0.87), water uptake ratio (r = 0.56 and optimum cooking time (r = 0.80) (Table 5). Significant correlations were found between gel consistency and ash, amylose, amylopectin, cooking time and water uptake ratio. It was positively correlated with amylopectin (r = 0.91), alkali spread value (r = 0.85) and negatively correlated with amylose (r = - 0.91), ash content (r = -0.91), water uptake ratio (r = - 0.70), optimum cooking time (r = - 0.87). Amylose content was negatively and significantly correlated with optimum cooking time (r = - 0.93), water uptake ratio (r = - 0.61) and amylopectin (r = - 1.00) (Table 5). The relation between amylose and amylopectin was perfectly negative meaning that they had negative and very highly significant (P < 0.0001) correlation. Optimum cooking time had significant correlation with most of the proximate composition and physicochemical parameters, but it had a strong correlation with gel consistency, amylose, amylopectin, ash and water uptake ratio (Table 5). The negative correlation was found between optimum cooking time and amylose content. Optimum cooking time was positively correlated with water uptake ratio. The correlation of cooking time was negative with gel consistency and positive with water uptake ratio.

Table 5. Correlation matrix among physicochemical and cooking quality traits of 15 rice genotypes

	WUR	ASV	ASH	AMY	AMP	OCT	SGL	ER
GC	-0.70***	0.85***	-0.91***	-0.91***	0.91***	-0.87***	0.25ns	-0.05ns
WUR		-0.54*	0.56*	-0.61***	0.61***	0.63***	-0.45**	0.15ns
ASV			-0.82***	0.95***	-0.95***	0.90***	0.17ns	-0.04ns
ASH				-0.87***	0.87***	0.80***	-0.38**	0.07ns
AMY					-1.00***	-0.93***	0.16ns	-0.08ns
AMP						0.93***	-0.16ns	0.08ns
OCT							-0.25ns	0.02ns

SGL	0.08ns

Where, WUR, water uptake ratio; ASV, alkli spread value, AMY, amylose content; AMP, amylopectin content; OCT, optimum cooking time; SGL, solid gruel loss; ER, elongation ratio; ns, non-significant; *, **, *** significant at 0.05, 0.01, 0.001 Probability level, respectively.

The negative correlation was found between optimum cooking time and amylose content. Optimum cooking time was positively correlated with water uptake ratio. The experiment by Thomas *et al.* (2013) agrees with the present study in the negative correlation of cooking time with amylose. However, it was found that the increase in amylose prolong the cooking time of rice grain (Odenigbo *et al.,* 2014). They found a positive and significant correlation between amylose content and water uptake ratio. The findings of Vanaja and Babu (2003) on the correlation studies of physicochemical and cooking quality traits revealed that the more the amylose content of varieties is the longer cooking time.

The correlation of cooking time was negative with gel consistency and positive with the water uptake ratio, which implies that harder gels needs more cooking time and water. This is in line with the finding of Shayo et al. (2006) on evaluation of physicochemical characters of rice cultivars from Morgorgo region, Tanzania.

Gel consistency was positively correlated with amylopectin and alkali spread value and it was negatively correlated with amylose content. This result is in line with the findings of Oko *et al.* (2012), where gel hardness was more related to the high amount of protein and amylose that contributed to longer cooking time and high water uptake ratio on the comparison of locally grown Nigerian rice varieties with two newly introduced varieties. The assessment of Juliano and Villarreal (1993) on different varieties across the world showed that protein, amylose and gel consistency widely varies across the environment. The report of Vanja and Babu (2003) on physicochemical and cooking characters of 56 high yielding rice varieties from eight different Asian countries also indicated that varieties with high amylose content have less water uptake capacity. However, the positive relation of amylose content with water uptake ratio, reported by Basri *et al*. (2015) on the evaluation of four high yielding local varieties from India is not in agreement with the present findings.

Conclusions

Intermediate amylose content, which was found in NERICA 4 and IR 72593. IR 70023, AT 401, IR 71901 and IR 73055, had the highest amount of ash content compared to the remaining genotypes. This reveals more amount of mineral content. Most of the genotypes had the highest amount of carbohydrate and energy content but the nutrient content was relatively better in AT 401 and IR 71901. Optimum cooking time, solid gruel loss and elongation ratio are the important traits that determine the cooking property of rice genotypes. The cooking property is said to be good when the genotype has minimum cooking time, low solid gruel loss and more elongation. The cooking time and solid gruel loss were significantly low in IR 29 and IR 72593, respectively. AT 401 and IR 71901, therefore, can be used for their high nutrient value. IR 29, and IR 72593 were found to be best in their best cooking quality. In fact,there should be a breeding program that improves the grain quality rice genotypes because most rice genotype evaluated were inferior in some important grain qualities.

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Conflict of Interest

The authors have declared that there is no conflict of interest.

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