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Full Length Research Paper

Evaluation of physicochemical characteristics of rice (*Oryza sativa .L.*) Varieties in Ghana

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This study evaluated grain appearance, cooking and eating qualities of 87 rice varieties. The varieties differed significantly at P > 0.001 for Grain length; volume expansion ratio, water uptake, length of blue Gel, Gel consistency, elongation ratio, alkaline spread value, gelatinization temperature and aroma. The gelatinization temperature (GT) was determined based on alkaline spreading score, and 64% of the rice varieties showed intermediate GT (70-74 ºC), 20% exhibited low GT (55-69 ºC), and only 16% of the rice varieties showed high GT above 74ºC. Hard gel consistency was observed in 71% of rice varieties evaluated, 22% recorded medium gel consistency, and only 7% of the rice varieties recorded soft gel consistency. Of the 87 test varieties, 34% were aromatic while 66% were not. Alkaline spread value had significant and positive correlation with water uptake, but gel consistency had negative correlation with volume expansion ratio. Based on the L/W ratio, 33 of the rice varieties had long slender grain type, 45 recorded medium slender grain and only 9 varieties recorded short bold grain. The characteristics of the various grain types make them suitable for different food preparations and meet the preferences of majority of consumers.

Key words: Gelatinization temperature, gel consistency, alkaline spread value, grain appearance, elongation ratio.

INTRODUCTION

Rice (*Oryza sativa L.)* is one of the leading food crops of the world and is the staple food of approximately one half of the world's population (Singh et al., 2003). About two thirds of the world population depends wholly on rice for their basic food consumption (Patil et al., 2014). In Africa, rice has increasingly become popular and it is reported to be the fastest growing food source (Nwanze et al., 2006). Rice is a primary source of income and employment for more than 100 million households in Asia and Africa and is cultivated in at least 114, mostly developing countries in the world (FAO, 2004). Quality is one of the selection principles prioritized by farmers and consumers of rice; thus farmers choose rice with traits that are needed for consumption as well as for production and sale (Horna et al., 2005). Consumer preference is based on appearance (milling quality, grain length and width), cooking and eating quality. The quality of a rice grain is determined by its physicochemical and physical properties. Physical quality has great impact on commercial rice production as it greatly influences on the final output as well as the consumer demand which directly contribute to the economic profitability of farmers and millers. Rice grain quality is one of the major concerns in rice production (Nanda, 2000). Cooking and eating qualities are controlled by biochemical components such as aroma, amylose content, gel consistency, alkaline spreading value/gelatinization temperature, and paste viscosity profiles (Bergman et al., 2004). Although breeding for improved grain quality has recently become a major focus in Africa, diversity study on grain quality traits is

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inadequate to understand the quality features of rice grains, hence, the need to characterize rice varieties available to breeders. This study was therefore conducted to determine the level of diversity of rice grain quality based on physicochemical and physical properties that will provide significant information for further rice breeding programs.

MATERIALS AND METHODS

The study was conducted at the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Ghana in 2014. The study used 87 rice genotypes, which were laid out in a randomized complete block design (RCBD) with three replications. Each plot comprises five plants planted singly in five 12 litre pots each filled with 12kg of sterilized top soil. Twenty one days old seedlings uprooted from the nursery were transplanted into the pots. All other agronomic practices were undertaken as recommended. After harvesting, seed samples were collected and sun-dried to 13% moisture content before milling. Samples were dehusked using THU- 34A Satake husker. The brown rice obtained from the dehusking was polished in a BSO8A Satake single pass friction rice pealer mill. All the laboratory analyses were repeated twice for each sample.

Physical Properties

Ten randomly selected whole rice grain samples were taken; length (L) and width (W) of rice grain were determined using vernier caliper. The average of 10 rice grains was taken for final value for both length and width of rice grain in millimeter (mm). Grain shape was determined by dividing the average length by the average width of rice kernel. Rice grains were categorized into long slender grain (LSG), short slender grain (SSG), medium slender grain (MSG), long bold grain (LBG) and short bold grain (SBG), based on the L/W ratio, using the method described by (Cruz et al., 2000).

Chemical Properties

Alkaline spreading value

Six whole milled grains were randomly selected for each variety, and were placed in a glass petri dishes containing 1.7% KOH in 10 ml of distilled water. The grains in the petri dishes were arranged with a pair of forceps to provide sufficient space between them. The rice samples in the petri dishes were then kept in a laboratory at room temperature for 23 hours (Anon, 2004).

Gel Consistency

Two gram (2g) of rice grains from each variety were grounded into fine powder and sieved through a 100 mm sieve; 100mg of the sieved flour was placed in a 50ml test tube with 0.25% thymol blue. 0.2 ml of ethanol and 2.0 ml of a solution of 11.2 g of potassium hydroxide (KOH) was added in 160 ml purified water. The samples were later placed in a boiled water bath for 8 minutes and allowed to cooled in an ice bath for 20 minutes. The samples were laid horizontally on a graphing paper and the length of the gel was determined using the method described by cruz etal. (2000), with slight modifications.

Aroma

At early vegetative stage, 10 cm leaf samples were collected from each rice variety. The rice samples were immediately placed in eppendorf tubes using leaf aromatic test (LAT). 10 ml potassium hydroxide (KOH 1.7 %) solution was pipette into eppendorf tubes and was covered for ten minutes for each of the rice samples used. Apanel of four people was used to determine the level of aroma in each of the samples. To prevent overwhelming panel members' senses, not more than 20 samples were scored at a time. Each set of samples had a known positive and negative control and any panel member who could differentiate between aromatic and non-aromatic controls was dropped from the panel. The leaf samples were scored as; 0= non aroma, 1= slightly aroma, 2 = moderate aroma and 3= strong aroma. Scores were averaged across panel members. Genotypes with average scores >1.5 and <1 were regarded as aromatic and non-aromatic respectively. Any genotype with scores 1-1.5 were re-evaluated until it was clearly defined as aromatic or non-aromatic.

Cooking characteristics

Elongation ratio

Ten randomly selected whole milled rice grains per variety was placed in a test tube containing 10 ml of distilled water and allowed to soak for 30 minutes. The test tubes were then placed in a boiled water bath for 10 minutes. Water in each test tube was drained and the cooked grains were kept in petri dishes for one minute. The length and width of each grain was measured using a vernier caliper, and the elongation ratio was estimated using the procedure described by Sood et al. (1983).

Volume expansion ratio

Five gram (5g) of milled rice grains were placed in a test tube containing 15ml of distilled water. The initial volumes of water were measured. The grains were allowed to cook for 10 minutes and then placed in boiled water for 20 minutes at 80 ^{0}C. The rice samples were dipped into 50 ml water and the increase in final water volume for each sample was measured using a calibrated measuring cylinder. The volume expansion ratio = $\frac{X-50}{Y-15}$, Where Y is the initial volume of water, and X final volume of water (Sidhu et al., 1975).

Water uptake

Two gram (2g) of rice sample for each variety was placed in a 50 ml test tube containing 10ml of distilled water for 30 minutes each. The test tubes were then placed in a boiled water bath for about 45 minutes at 80°C. Three test tubes without rice grains were each filled with 10 ml of water and placed in the water bath as controls. After cooling, the supernatant was transferred into a graduated measuring cylinder and the level of water was measured. Water uptake was determined by the formula: water uptake = $\left(\frac{100}{2g}\right)$*actual water absorbed (Anon, 2004).

Statistical Analysis

Data collected were analyzed using GenStat (12th edition package).

RESULTS AND DISCUSSION

The quality of rice grains depends on their physicochemical characteristics which are influenced by genotype (Kishine et al., 2008). The physical appearance, cooking and eating characteristics of rice highly influences consumers' preferences. Consumers' preference for grain quality characteristics is thus highly prioritized trait for many rice breeders around the world.

Physical characteristics of rice grain

Size and shape of grains are among the first quality criteria that breeders consider in developing new cultivars. The result revealed significant variability among the rice genotypes for all the physical traits studied. CRI-2 had the highest 100 grain weight 4.1 g followed by CRI-45 3.9g while N22 had the lowest in 1.8 g. CRI-45 had the longest grains (8.03 mm) followed by CRI- 2 7.57 mm) and GR-21 the lowest 5.43 mm. This difference in length of grain might be due to the genetic make-up of rice accessions. The result is in line with the findings of Santhi et al. (2014). Grain size in breeding applications is usually assessed by the grain weight, which is positively correlated with several characters, including grain length, grain width and grain thickness (Xuet al., 2002). Grain shape or length/width (L/W) ratio is an important features for grain quality assessment (Rita et al., 2008). Wider variability was observed in the varieties used ranging from 2.15- 4.5 for GR 21 and IR 81412-B-B-82-1 (Table 1). The variation in this trait might be attributed to environmental factors. Based on grain shape, the rice samples were classified into three, 33 of the varieties had long slender grain, 45 medium slender grain, and only 9 varieties had short bold grain. The result is in line with the findings of Meena et al. (2010), but also contradict the findings of Vanaja et al. (2006), Bhonsle et al. (2010). Preference for rice grain characteristics varies with different consumer groups, but long and slender rice grain is favored by most consumers around the world.

Cooking characteristics

The result revealed significant difference among varieties studied, indicating considerable variability among the genotypes for volume expansion ratio, grain length after cooked. Length of the cooked grain ranges from 6.97mm to 9.16mm with a mean value of 8.28mm and the width after cooking ranges from 2.53 mm to 3.47mm (Table 1). The cooking quality of rice is influenced by the gelatinization and retrogradation characteristics of its starch (Zhou et al., 2003).

Rice grains absorb water and increase in volume through an increase in length or width during cooking. A length-wise increase without an increase in girth is a desirable characteristic in high quality premium rice (Hossain et al., 2009). SIK-353-A 10 had the longest grain length after cooked (GLAC) and the least in GR-21. However, GLAC was reported to be influenced by genetic factors and environmental, especially temperature during ripening. WAB-2081-WAC B-TGR4- B had largest GWAC lowest in TXD 88. The coefficient of variation for elongation ratio was 10.4% (Table 2). Among the test varieties, the elongation ratio ranged from 1.09 (WAB 2125- WAC B-TGR3- WAT B1) to 1.67(IR 74371-54-1-1). The result contradicts the findings of Yaday et al. (2007). Volume Expansion (VE) over cooked was taken as the ratio between volume of cooked rice and initial volume of raw rice. Volume expansion values of selected varieties varied from a maximum of 2.77 in ROX-15 and minimum in 1.01 DKA-M (Table 1). However, a significant difference was observed in VE values, indicating variation among the varieties. It is a positive character for the lower income group for whom quantity is an important criterion. However, the higher the volume expansion ratio, the lower the energy content per unit volume.

Chemical characters

Alkaline spreading value gives an idea of gelatinization temperature (GT). The result revealed significant difference among the tested genotypes. Considerable variation existed among rice genotypes for these traits, from the 87 rice accession, 64% had intermediate, 20% low and 16% high, indicating that gelatinization temperature influences cooking time and samples with high gelatinization temperature required more time to cook compared to rice variety with low GT Chatterjee et al. (1985). Varieties with a low gelatinization temperature crumble completely in 1.7 percent KOH solution, those with intermediate gelatinization temperature showed

Table 1. Physicochemical character of 87 rice varieties.

Accession Name	VER[1]	GLAC	WU	GWAC	GL	GW	LBR	ELR	GC	ARM	LBG
WAB 2081-WAC B-TGR4-B	1.84	8.70	175.64	3.47	7.43	2.63	2.83	1.2	H	A	27.6
WAB 2125-WAC B-1-TGR3-WAT B1	2.49	7.70	75.86	2.73	7.23	2.37	3.06	1.1	H	P	29.6
IR 841 (CHECK)	2.21	8.63	274.44	2.97	6.27	2.20	2.85	1.4	H	P	30.0
DKA-M2	1.82	8.70	275.13	3.13	6.43	2.20	2.93	1.4	M	A	40.3
JASMINE 85	1.94	8.43	250.98	2.67	7.13	2.30	3.14	1.2	S	P	61.6
FAROX 508-3-10-F43-1-1	1.40	8.43	75.18	2.80	6.97	2.27	3.06	1.2	H	A	30.7
FAROX 508-3-10-F44-2-1-1	1.10	8.57	99.92	2.60	6.27	1.83	3.42	1.3	S	A	57.3
WAB 2098-WAC2-1-TGR2-WAT B2	1.74	8.50	125.31	2.97	6.57	2.07	3.19	1.3	H	P	31.7
WAB 2056-2-FKR2-5-TGR1-B	1.21	8.77	268.98	3.13	6.43	2.30	2.83	1.4	H	A	30.7
WAB 2060-3-FKR1-WAC2-TGR4-B	1.41	8.23	49.12	2.77	7.27	2.27	3.24	1.1	M	P	44.7
TXD 88	1.52	8.07	125.39	2.53	6.53	2.73	2.39	1.3	H	A	28.3
WAB 2098-WAC3-1-TGR1-4	2.10	8.20	224.94	2.87	6.83	1.73	3.94	1.2	H	P	28.8
WAB 2076-WAC1-TGR1-B	2.39	7.50	275.19	2.70	6.43	2.43	2.65	1.2	H	A	29.3
WAB 2081-WAC2-2-TGR2-WAT B3	1.34	8.90	50.44	2.87	7.40	2.17	3.42	1.2	H	A	33.0
GBEWAA	2.16	8.23	270.69	2.90	6.60	1.70	3.98	1.3	M	P	46.7
PERFUME IRRIGATED	1.97	8.23	149.84	2.83	6.70	2.33	2.87	1.2	H	P	28.7
WAS-122-13-WAS-10-WAR	1.61	7.57	149.12	2.77	6.40	2.27	2.82	1.2	H	A	29.3
LONG GRAIN ORDINARY 2	1.76	7.87	174.87	2.77	6.97	1.50	4.63	1.1	H	A	30.0
EXBAIKA	1.59	8.43	125.32	2.73	6.57	2.40	2.74	1.3	M	P	44.3
WAS-163-B-5-3	1.48	8.53	75.84	2.93	6.40	2.00	3.32	1.3	H	P	29.7
FAROX 15	2.77	8.67	275.62	3.10	6.53	2.30	3.12	1.3	H	A	29.3
PERFUME SHORT	1.19	9.03	124.98	2.87	6.73	1.70	3.96	1.3	H	P	31.7
KATANGA	1.59	8.13	276.13	2.73	6.33	2.17	2.94	1.3	H	A	28.3
TOX 3107	1.50	8.17	176.06	3.07	6.93	2.07	3.36	1.1	H	A	29.3
ANYOFULA	2.61	8.07	300.53	2.83	7.43	2.50	2.97	1.1	M	A	44.0
NABOGU	1.89	7.97	125.67	2.67	6.30	2.27	2.79	1.3	M	A	44.0
GR 21	2.04	6.97	150.89	2.60	5.43	2.53	2.15	1.3	H	A	28.6
PHKA RUMDON	2.27	8.63	348.74	3.10	7.17	1.70	4.22	1.2	H	A	30.3
MLI 20-4-1-1-1	1.56	8.60	126.52	3.00	7.33	2.63	2.82	1.2	H	A	30.0
DKA-M2	1.02	7.77	150.46	2.77	6.30	1.70	3.71	1.2	M	A	47.3
SIK 353-A-10	1.89	9.17	200.07	2.93	6.97	2.30	3.06	1.3	M	A	41.0
DK 3	2.15	8.70	125.29	3.10	6.37	2.30	2.78	1.4	H	P	29.0
MLI 6-1-2-3-2	1.30	8.13	50.08	2.90	6.80	2.23	2.23	1.2	H	A	29.6
MLI 25-1-2	1.55	8.73	124.74	3.07	6.67	2.27	2.27	1.3	H	P	30.6

Table 1. Cont.

DKA 4	1.45	7.80	75.92	2.63	5.83	2.13	2.13	1.3	M	A	44.0
DKA- M8	1.53	7.93	100.04	2.87	6.33	2.33	2.33	1.3	H	A	38.6
SIK 350-A-150	1.52	8.57	100.29	3.00	5.73	2.17	2.17	1.5	H	A	30.3
DKA-M11	1.16	7.97	123.64	2.77	7.13	1.93	1.93	1.1	M	A	44.6
DKA 22	1.63	7.80	75.57	2.93	6.90	2.13	2.13	1.1	H	A	31.0
DKA-M9	1.62	8.27	125.30	2.77	6.30	2.17	2.17	1.3	S	A	60.0
DKA 1	1.63	8.67	125.18	2.73	7.43	2.37	2.37	1.2	H	A	29.3
DKA 21	1.33	8.00	50.01	2.97	6.97	2.33	2.33	1.2	M	A	46.6
MLI 20-4-3-1	8.33	8.03	74.40	2.87	7.20	2.23	2.23	1.1	H	P	27.6
SBT 70	2.74	8.33	274.94	2.90	7.40	2.20	2.20	1.1	H	P	35.6
BASMATI 113	1.49	8.33	126.23	2.93	6.60	2.27	2.27	1.2	S	P	59.3
AGRA RICE	2.04	8.03	75.55	3.03	7.13	2.00	2.00	1.2	H	P	30.0
BASMATI 123	1.50	8.07	125.05	3.07	6.33	2.10	2.10	1.3	H	P	29.0
CRI-30	1.70	8.20	145.18	2.93	6.90	2.50	2.50	1.2	H	A	31.6
CRI-2	1.61	8.73	99.51	2.97	7.57	2.33	2.33	1.2	H	A	30.6
CRI-45	1.69	8.83	98.79	2.83	8.03	2.30	2.30	1.1	M	A	46.6
CRI-73	1.82	8.10	124.29	2.77	6.57	2.43	2.43	1.3	H	A	30.3
CRI-48	2.32	8.40	199.24	3.20	6.60	2.43	2.43	1.3	H	P	30.0
NERICA 1	1.37	8.07	74.24	2.70	6.70	2.37	2.37	1.2	H	A	32.0
AFRK-7	1.57	8.30	75.47	3.07	7.23	2.23	2.23	1.2	H	A	35.0
AFRK-8	2.61	8.10	123.99	2.83	6.33	2.53	2.53	1.3	H	P	33.6
AFRK-5	1.44	8.47	124.97	2.97	6.80	2.40	2.40	1.3	H	P	28.6
AFRK-13	1.49	8.33	124.48	2.87	6.90	2.37	2.37	1.2	M	A	45.6
NERICA 4	1.44	8.43	50.13	3.00	6.63	2.27	2.27	1.3	M	A	46.0
AFRK-6	1.67	8.03	124.43	2.60	6.93	1.83	1.83	1.2	H	A	31.6
AFRK-2	1.37	9.03	79.61	2.80	6.43	2.37	2.37	1.2	H	P	28.3
AFRK-11	1.90	8.27	175.04	2.73	6.83	2.50	2.50	1.3	H	P	29.3
NERICA 14	1.87	7.77	124.13	3.10	7.27	2.50	2.50	1.1	S	P	64.0
AFRK-9	1.47	8.47	76.02	2.90	6.43	2.53	2.53	1.2	H	P	31.6
AFRK-3	1.80	8.20	251.63	2.93	6.57	2.33	2.33	1.3	H	A	30.6
AFRK-1	1.24	8.37	125.43	2.77	7.20	2.23	2.23	1.1	H	P	36.0
AFRK-10	1.57	8.30	101.10	2.87	7.27	2.37	2.37	1.1	H	A	33.6
AFRK-5	1.95	8.10	224.32	2.77	8.34	2.27	2.45	1.3	H	A	33.0
AFRK- 4	1.95	8.10	224.32	2.77	6.40	2.30	2.85	1.3	H	A	32.0
IR 74963-2-6-2-5-1-3-3	1.16	8.33	225.42	2.80	6.87	2.37	2.89	1.3	H	A	31.0
IR 81412-B-B-82-1	1.61	8.50	200.10	2.87	7.23	1.60	4.52	1.2	H	A	30.3
IR 55419-04	2.16	8.43	299.35	2.80	6.10	2.30	2.66	1.4	H	A	31.0
IR 79913-B-179-B-4	1.19	7.60	75.20	2.87	6.17	2.47	2.50	1.2	H	A	31.3
APO	2.68	8.23	76.41	2.87	6.30	2.47	2.56	1.3	H	A	33.3
N22	1.52	8.23	76.61	2.90	6.03	2.43	2.60	1.4	M	A	43.0

Table 1. Cont.

IR 77298-14-1-2-10	1.75	7.70	124.68	2.80	5.93	2.53	3.34	1.3	H	P	31.6
KALIAUS	1.66	8.70	225.52	2.93	6.97	2.30	3.04	1.3	M	A	44.0
UPL RI 7	1.82	8.63	200.10	2.90	6.30	2.37	2.66	1.4	M	A	44.3
KALIA	1.52	7.57	99.46	2.73	6.57	2.30	2.93	1.2	S	A	60.0
IR 74371-46-1-1	2.05	7.97	125.12	2.73	5.87	2.37	2.50	1.4	H	A	29.6
IR 74371-54-1-1	1.93	9.07	124.64	3.03	5.47	2.47	2.25	1.7	H	A	28.6
IR 80411-49-1	1.42	8.73	275.63	2.97	6.67	2.43	2.74	1.3	H	A	29.3
IR81023-B-116-1-2	2.19	8.23	251.47	2.97	6.07	2.63	2.31	1.4	H	A	30.3
WAY RAREM	2.39	7.80	199.74	2.97	6.37	2.57	2.31	1.2	H	P	30.6
VANDANA	1.67	8.40	148.21	2.93	7.00	1.70	2.48	1.2	M	A	41.6
IR 77298-5-6-18	1.48	7.63	84.32	2.90	6.60	2.23	4.12	1.2	H	A	36.6
IR 74371-70-1-1	2.60	8.10	148.44	293	6.37	2.33	2.95	1.3	H	A	29.6
UPL RI 5	2.73	8.77	50.39	2.93	6.37	2.00	3.19	1.4	M	A	46.0

VER: volume expansion ratio; GLAC: grain length after cooked; WU: water uptake; GWAC: grain width after cooked; GL: Grain length; GW: Grain width; LWR: length and width ratio; ELR: elongation ratio; ARM: Aroma and LBG: Length of blue gel.

incomplete fragmentation, while the rice varieties with high gelatinization temperature remains generally unaffected in the alkaline solution.

Rice differs in gel consistency from soft gel (61-100), through medium gel (41-60) to hard gel (26- 40) (Cagampang et al., 1973). In this study, 22 varieties had medium gel, 6 soft gel and 63 hard gel. The results showed that cooked rice samples with hard gel consistency harden faster compared to those with soft gel consistency and remain soft even upon cooling (Juliano et al., 1979). Among the varieties used, the length of blue gel was highest in DKA-M9 and lowest in MLI 20-4-3-1. Most of these grain quality traits of rice are controlled by quantitative trait loci (QTLs) showing continuous variation in rice progeny (He et al., 1999). However, GC is controlled either by the *wx*gene (Lanceras et al., 2000).

Water uptake was highest in PHKA RUMDOM (348.74) followed by ANYOFULA (300.53) and IR 55419-04 (299.35) and lowest in DKA (50.1). This result contradicts the early findings of Shilpa (2010). The variation might be attributed to drying methods and different varieties used. This showed that short and medium grain varieties have higher water absorption than long grain.

Aromatic rice attracts high price in many markets around the world, from the 87 test genotypes, 34% were aromatic while 66% were not. Aroma in majority of aromatic rice is caused by an 8bp deletion in exon 7 of the betaine aldehyde dehydrogenase 2 (BADH2) gene Fitzgerald et al.(2008). However, some aromatic varieties have been found to have different alleles/genes either from the 8bp deletion in exon 7 of the BADH2 gene (Kovach etal., 2009). It would be interesting to find whether any of these aromatic genotypes have novel alleles/genes for aroma. The aromatic genotypes could be exploited in future breeding programs.

Correlation among grain quality traits

Correlation analysis revealed significant associations among the tested physicochemical traits. Alkaline spread had significant and positive correlation with water uptake and non-significant correlation

Table 2. Descriptive statistics for various physiochemical traits of 87 rice varieties.

Variable	Mean ± SD	CV	Min	Max	Range
ASV	4.52±O.7797	21.1	2.00	7.00	5.00
GC	35.43±3.756	13.0	27.00	64.00	37.00
ARM	0.860±0.3075	43.8	0.333	1.96	1.63
ELR	1.2518±0.106	10.4	1.085	1.49	0.40
LWR	1.56±0.329	13.3	3.760	4.00	1.00
GLAC	8.279±0.4301	8.1	6.967	9.16	2.20
GWAC	2.877±0.1894	6.6	2.533	3.20	0.66
GL	6.670±0.4301	7.9	5.467	8.03	2.56
GW	2.253±0.1822	9.9	1.503	2.73	1.23
VER	1.765±0.2675	18.9	1.110	2.83	1.726
WUP	150.322±0.896	0.8	49.116	300.52	250.88
100GW	2.86±0.3962	8.6	2.270	3.987	1.287

Note: ASV, alkaline spread value; SD, standard deviation; GC, gel consistency; ELR, elongation ratio; LBR, length and width ratio; GLAC, grain length after cooking; GWAC, grain width after cooking; GL, grain length; GW, grain width; VER, volume expansion ratio; WUP, water uptake; 100GW, hundred grain weight.

Table 3. Pearson's correlation coefficients of various Physicochemical traits.

Traits	ASV	ELR	GC	GL	GLAC	GWAC	VER	WU
ASV	-							
ELR	0.09	-						
GC	-0.10	0.01	-					
GL	-0.05	0.76***	-0.03	-				
GLAC	0.08	0.49**	-0.04	0.17**	-			
GWAC	0.09	0.16	-0.05	-0.01	0.28***	-		
VER	0.33	0.08	0.13*	-0.06	0.04	0.04	-	
WU	0.27***	0.02	0.13*	0.01	0.07	0.09	0.35***	-

*, ** and *** = significant at p< 0.05, p< 0.01 and p< 0.001 respectively.
ASV, alkaline spreading value; ELR, elongation Ratio; GC, gel Consistency; GLAC, grain length after cooked; GWAC, grain width after cooked; VER, volume expansion ratio; WU, water uptake.

with gel consistency (Table 3). The result is in confirmation with the findings of Sagar et al. (1988). Gel consistency had significant and negative correlation with volume expansion ratio and water uptake respectively. Grain length had significant and positive correlation with grain length after cooked and significant correlation with grain thickness, indicating that an increase in one trait result in an increase in the opposite traits. Elongation ratio had significant and positive correlation with grain length, significant correlation with water uptake, significant correlation with grain length and significant and positive correlation with grain length after cooked. Gel consistency had a significant negative correlation with volume expansion ratio, indicating that an increase in one trait resulted to a decrease in the opposite trait. Grain length after cooked had significant correlation with grain width after cooked. The result is in agreement with Danbaba et al. (2011), Begun et al. (2006). In contrast, Tomar et al. (1985) did not find any correlation between grain size and shape. It had significant positive association between volume expansion ratio and water uptake.

CONCLUSION

The results revealed that varietal variability existed considerably in all the physical and chemical properties of the different rice varieties studied. Also, varietal differences were evident among the rice accessions for sensory and cooking characteristics. The difference in these traits could be exploited in rice breeding programes to improve grain quality traits. Hence, this study needs to be repeated using molecular markers to show diversity among all the grain quality traits studied.

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