# Physico-Chemical and Cooking Quality of Indica and Japonica Rice Hybrids

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*Abstract:* - Locally produced rice cultivars in Kenya have poor culinary qualities therefore, urban consumers prefer imported rice. The imported rice is expensive and unaffordable to the rural poor. Therefore, improving the culinary qualities of the local rice cultivars will increase their consumption and competitiveness in the local market. The objective of this study was to determine the physico-chemical and cooking quality of crosses between japonica and indica rice. Seven $F_{2.3}$ families were selected from segregating populations and evaluated for two seasons. The physical quality parameters determined were grain length grain shape while the chemical and cooking qualities were alkali spreading value, gelatinization temperature, gel consistency, aroma, and cooking time. The data for the grain quality was subjected to analysis of variance using GENSTAT 15$^{th}$ edition. The results showed that the $F_{2.3}$ families of NERICA 4 x MWUR 4, NERICA 4 x NERICA 1 and NERICA 10 x KUCHUM exhibited slender grain shape while NERICA 4 x MWUR 4, NERICA 4 x NERICA 1 and WAB-56-104 x NERICA 4 had soft cooked texture and recorded low gelatinization temperatures of 55 to 69$^{o}$C and cooked fast in 22.3 to 23.3 minutes. The $F_{2.3}$ families of WAB-56-104 x NERICA 4, NERICA 4 x MWUR 4, MWUR 4 x NERICA 4 and CG 14 x NERICA 10 had mild aroma while NERICA 4 x NERICA 1, NERICA 13 x K45 and NERICA 10 x KUCHUM were non-aromatic. Therefore, the $F_{2.3}$ families of MWUR 4 x NERICA 4, NERICA 4 x NERICA 1 and WAB-56-104 x NERICA 4 had better cooking and physico-chemical quality. However, the check variety Basmati 370 was outstanding for physical grain quality and aroma compared to the non-Basmati rice genotypes suggesting that Basmati 370 has implication for future breeding. The negative and positive correlations among the grain quality traits indicated that efforts aimed at selecting rice varieties with improved cooking qualities should warrant the consideration of the physico-chemical properties of rice grain. Thus there is need to advance these $F_{2.3}$ families to $F_6$ or $F_7$ in order to ascertain their culinary qualities.

*Key-Words:* - Aroma, correlation, physico-chemical quality, grain quality, *Oryza sativa*

## 1 Introduction

Rice (*Oryza sativa*) is the second most important food crop after maize and provides over 20 % of the daily calorie intake for 3.9 billion people globally [1]. Annual rice production in Africa was estimated at 31 million t from 11 million hectares under cultivation [2]. In Kenya, annual rice production was estimated at 140,000 metric tons against a demand of 540,000 metric tons [3]. This huge gap was fulfilled through imports from Pakistan, China, India and Vietnam [8].

Rice breeding focuses mainly on yield improvement, breeding for tolerance to biotic and abiotic stresses. However, no attempts have been made to breed for grain quality in Kenya [4]. Rice consumers in Kenya prefer imported to locally produced rice. This is attributed to poor nutritional and cooking quality of the locally produced rice [5]. Therefore, it is important to identify outstanding rice varieties through characterization of the available upland rice varieties which can be used directly to improve productivity and culinary qualities of the local rice cultivars grown by smallholder farmers.

A preferred rice variety should not only have good agronomic performance but also high grain quality that is widely acceptable to farmers, millers and consumers [6]. Consumer preference for grain shape and size varies. Some consumers prefer short, bold grain while others prefer medium long grain [7], but long slender aromatic grain is preferred by consumers in Kenya [8].

Previous studies suggested that aromatic and long rice grains are highly preferred and fetch premium price at the international market [7]. The cooking and eating qualities of rice can be influenced by aroma, amount of amylose content, gel consistency and gelatinization temperature [7]. Juliano [9] reported a positive and significant association between gelatinization temperature and cooking time, but gelatinization temperature was negatively correlated with the texture of cooked rice. Rice varieties with higher gelatinization temperature normally have low amylose content [10]. To increase adoption and consumption of a rice variety, rice breeders should take into consideration grain shape and grain size when developing new rice varieties for commercial production [11]. Therefore, the objective of this study was to determine the cooking and physico-chemical qualities of $F_{2.3}$ families as a criterion to select superior genotypes for improvement of local rice cultivars gown in Kenya.

## 2 Materials and Methods

### 2.1 Site Description

The experiment was conducted during the cropping season of 2016 and 2017 at the Industrial Crops Research Centre of the Kenya Agricultural and Livestock Research Organization. The research station is located in Mwea Division, Kirinyaga County, Kenya. The site lies on a latitude 0 37’S and longitude 37 20’E on an elevation of 1159 m above sea level. The soil type is nitosol with a $_{P}$H of about 5.65 [12].

### 2.2 Plant Materials

Seven outstanding $F_{2.3}$ families were selected from 16 segregating rice populations and evaluated at Mwea and Kirogo experimental farm (Table 1). At maturity, the rice were harvested and dried to 14 % moisture content, processed and subjected to physico-chemical and culinary quality analysis.

Table 1. Characteristics of the rice germplasm used in the study

| Germplasm | Characteristics |
|---|---|
| Basmati 370 (check) | Strong aroma, good grain quality and high adaptability to local conditions |
| WAB-56-104 (check) | High yield (7.5 t $ha^{-1}$), mild aroma and blast tolerant |
| MWUR 4 (check) | High yield (6 t $ha^{-1}$), high adaptability to local conditions |
| MWUR 4 x NERICA 4 | MWUR 4 - high yield (6 t $ha^{-1}$); NERICA 4 - blast tolerance and long grains |
| NERICA 10 x KUCHUM | NERICA 10 - long grains, blast tolerance; KUCHUM - blast tolerance, earliness |
| NERICA 13 x K45 | NERICA 13 - long grains, tolerance to leaf blast; K45 - high yielding (7.6 t $ha^{-1}$), earliness and well adapted to irrigated lowlands upland areas |
| NERICA 4 x MWUR 4 | NERICA 4 - blast tolerance and long grains; MWUR 4 - high grain yield (6 t $ha^{-1}$) |
| NERICA 4 x NERICA 1 | NERICA 4 - blast tolerance, long grains; NERICA 1 -earliness, aroma |
| CG 14 x NERICA 10 | CG 14 - earliness, mild aroma; NERICA 10 - long grains, blast tolerance |
| WAB-56-104 x NERICA 4 | WAB-56-104 - high grain yield (8 t $ha^{-1}$), good grain quality; NERICA 4 - blast tolerance, long grains |

### 2.3 Determination of Physical Grain Quality

The physical properties of grain quality evaluated were grain length and grain shape. Grain length of 10 milled rice kernels for each genotype was measured using a vernier caliper (Model 530-312, Mitutoyo, Japan). Average length and width of the kernels were calculated [13]. The length of the rice kernels were classified as very long (more than 7.5 mm), long (6.61 to 7.5 mm), intermediate (5.51 to 6.6 mm) and short (≤ 5.5 mm) [10]. Grain shape was determined by dividing the mean length of each kernel by its corresponding breadth. Grain shape of the rice kernels were categorized as slender (over 3.0), medium (2.1 to 3.0), bold (1.1 to 2.0) and round (≤ 1.0) [10].

### 2.4 Determination of Chemical Grain Quality

The chemical grain quality properties evaluated were alkali spreading value, gelatinization temperature, gel consistency, aroma and cooking time. Alkali spreading value was determined using the procedure described by Little *et al.*, [14]. Gelatinization temperature of the rice kernels was determined by relating the kernel spreading values with the corresponding temperature range, the temperature normally vary between 50$^{o}$C to 79$^{o}$C and classified as low (55 to 69°C), intermediate (70 to 74°C) and high 75 to 79°C [10].

Gel consistency was determined according to the procedure described by Cagampang *et al.*, [15]. Gel consistency of the rice kernels were classified as follows: soft gel (61 to 100 mm), medium (41 to 60 mm) and hard gel (26 to 40 mm) [10].

Aroma was determined by weighing 2 g of milled rice kernels from each genotype and soaking it in 10 ml 1.7 % potassium hydroxide solution at room temperature in a covered glass petri-plate for about 1 hour. The soaked rice kernels were rated on a scale of 1 to 4 by a test panel as follows: 1- no aroma; 2- slight aroma; 3- moderate aroma; and 4- strong aroma [16].

Cooking time was determined by weighing 5 g of milled rice from each genotype and pouring it into 135 ml of boiling distilled water in a 400 ml beaker. After every ten minutes, 5 to 10 kernels were randomly taken out with a ladle and pressed between two petri dishes. The grains were considered cooked when they no longer have opaque centres and the time was recorded. The cooking time was determined using the formula: Cooking time = Final time - Initial time [17].

### 2.5 Data Analysis

The data for grain quality was subjected to analysis of variance according to Gomez and Gomez [18] using GENSTAT 15$^{th}$ edition. Descriptive statistic was used for grain dimension. Their means were separated using the least significant differences (LSD) at P≤0.05. The interrelationships among grain quality traits were computed according to Pearson [19] using the statistical model $P_{xy}= \frac{\sigma xy}{\sigma x \sigma y}$................................................Equation (1)

Where: $\sigma_x\sigma_y$= population standard deviations and $\sigma_{xy}$= population variance.

## 3 Results

### 3.1 Physical Grain Quality

The results for physical grain quality are presented in Table 2. There were significant differences (P≤0.05) among the $F_{2.3}$ families for grain length. Grain length of the $F_{2.3}$ families varied from 6.84 to7.06 mm with a mean value of 6.93 mm. Maximum grain length was recorded in MWUR 4 x NERICA 4 while NERICA 4 x MWUR 4 had the least grain length. The check variety Basmati 370 had a very long grain length compared to all the $F_{2.3}$ families evaluated.

Grain width was not significantly different (P≤0.05) among the genotypes tested. Grain width of the $F_{2.3}$ families varied from 2.10 to 2.68 mm with a mean value of 2.43 mm. The $F_{2.3}$ families of MWUR 4 x NERICA 4 and NERICA 13 x K45 exhibited high grain width while NERICA 4 x MWUR 4 had the lowest grain width.

There were significant differences (P≤0.05) for length to width ratio among the $F_{2.3}$ families. Length to width ratio varied from 2.54 to 3.19 with a mean value of 2.94. The $F_{2.3}$ families of NERICA 4 x MWUR 4, NERICA 10 x KUCHUM and NERICA 4 x NERICA 1 exhibited high length to width ratio while NERICA 13 x K45 had the lowest. The check variety Basmati 370 had the highest length to width ratio among the tested genotypes.

Table 2. Physical grain quality of $F_{2.3}$ families grown at Mwea Research Station during 2016 and 2017 cropping season

| Genotype | Grain length (mm) | Grain width (mm) | Length to width ratio | Grain shape category | Grain length category |
|---|---|---|---|---|---|
| Basmati 370 (check) | 7.86 | 2.67 | 3.32 | Slender | Very long |
| WAB-56-104 (check) | 6.82 | 2.45 | 2.78 | Medium | Long |
| MWUR 4 (check) | 6.75 | 2.40 | 2.81 | Medium | Long |
| MWUR 4 x NERICA 4 | 7.06 | 2.68 | 2.94 | Medium | Long |
| NERICA 10 x KUCHUM | 6.92 | 2.20 | 3.15 | Slender | Long |
| NERICA13 x K45 | 6.72 | 2.65 | 2.54 | Medium | Long |
| NERICA 4 x MWUR 4 | 6.69 | 2.10 | 3.19 | Slender | Long |
| NERICA 4 x NERICA 1 | 6.75 | 2.20 | 3.07 | Slender | Long |
| CG 14 x NERICA 10 | 6.89 | 2.45 | 2.81 | Medium | Long |
| WAB-56-104 x NERICA 4 | 6.84 | 2.50 | 2.74 | Medium | Long |
| Grand Mean | 6.93 | 2.43 | 2.94 | - | - |
| CV % | 2.1 | 0.10 | 0.13 | - | - |
| LSD 5 % | 0.42 | 0.23 | 0.56 | - | - |

LSD = Least significant differences of means at ($P \leq 0.05$), CV = Coefficient of variation

### 3.2 Chemical Grain Quality

The results for chemical grain quality are presented in Table 3. There were significant differences ($P \leq 0.05$) for cooking time among the rice genotypes. The $F_{2.3}$ families of NERICA 13 x K45, NERICA 10 x KUCHUM took longer time to cook while NERICA 4 x NERICA 1 and MWUR 4 x NERICA 4 cooked fast.

The sensory test showed that the $F_{2.3}$ families of MWUR 4 x NERICA 4, NERICA 4 x MWUR 4, CG 14 x NERICA 10 and WAB-56-104 x NERICA 4 were slightly aromatic while NERICA 10 x KUCHUM, NERICA 13 x K45 and NERICA 4 x NERICA 1 were non-aromatic. The check Basmati 370 had strong aroma compared to all the $F_{2.3}$ families evaluated.

The alkali digestion of the rice kernels varied from 2 to 7 among the genotypes indicating a wide range of gelatinization temperature.

The $F_{2.3}$ families of NERICA 4 x NERICA 1, MWUR 4 x NERICA 4 had alkali digestion scale 6 while WAB-56-104 x NERICA 4 had scale 7 but NERICA 10 x KUCHUM exhibited scale 4. The $F_{2.3}$ families of NERICA 4 x MWUR 4 showed scale 2 while NERICA 13 x K45 and CG 14 x NERICA 10 had scale 3.

Gelatinization temperature was significantly different ($P \leq 0.05$) among the rice genotypes. The $F_{2.3}$ families of NERICA 13 x K45 had the highest gelatinization temperatures while NERICA 4 x NERICA 1 and MWUR 4 x NERICA 4 had the lowest.

There was marked variation in gel length among the genotypes tested. It varied from 45 to 65 mm. The $F_{2.3}$ families of WAB-56-104 x NERICA 4, NERICA 4 x NERICA 1 and MWUR 4 x NERICA 4 exhibited the highest gel consistency while NERICA 13 x K45 had low gel consistency.

Table 3. Chemical grain quality of $F_{2.3}$ families grown at Mwea Research Station during 2016 and 2017 cropping season

| Genotype | Aroma test | Cooking time (min) | Alkali spreading value | Gelatinization Temperature ($^0$C) | Temperature category | Gel Consistency (mm) | Gel category |
|---|---|---|---|---|---|---|---|
| Basmati 370 (check) | Strong | 23.67 | 4 | 70.00 | Intermediate | 40 | Hard gel |
| WAB-56-104 (check) | No | 24.67 | 6 | 65.00 | Low | 65 | Soft gel |
| MWUR 4 (check) | No | 25.33 | 6 | 55.00 | Low | 64 | Soft gel |
| MWUR 4 x NERICA 4 | Slight | 23.33 | 6 | 58.67 | Low | 63 | Soft gel |
| NERICA 10 x KUCHUM | No | 43.33 | 2 | 75.00 | High | 53 | Medium |
| NERICA 13 x K45 | No | 45.33 | 3 | 79.00 | High | 45 | Medium |
| NERICA 4 x MWUR 4 | Slight | 37.33 | 2 | 76.00 | High | 48 | Medium |
| NERICA 4 x NERICA 1 | No | 22.33 | 6 | 57.00 | Low | 63 | Soft gel |
| CG 14 x NERICA 10 | Slight | 40.67 | 3 | 78.00 | High | 60 | Medium |
| WAB-56-104 x NERICA 4 | Slight | 22.67 | 7 | 69.00 | Low | 65 | Soft gel |
| Grand Mean | - | 39.47 | 4.3 | 67.87 | - | 60.6 | - |
| CV % | - | 0.94 | 0 | 0.10 | - | 0 | - |
| LSD 5 % | - | 1.9 | 0 | 0.31 | - | 0 | - |

LSD = Least significant differences of means at (P≤0.05), CV = Coefficient of variation

### 3.3 Correlations between Physico-Chemical Characters

There were significant (P≤0.05) correlations among the physico-chemical characters (Table 4). Rice genotypes that exhibited longer cooking time (r = 0.58**) had low gel consistency but those with low alkali digestion value had high gelatinization temperature and took longer cooking time (r = 0.35**).

The $F_{2.3}$ families with long grains had shorter cooking time (r = -0.69**) and low gel consistency (r = -0.61**) but higher length to width ratio (r = 0.55*) while rice genotypes with high grain length had high grain width (r = 0.509*) but lower length to width ratio (r = -0.383*) and gel consistency (r = -0.698**).

Table 4. Correlations between physico-chemical characters

| | Alkali spreading value | Length to width ratio | Cooking time (min) | Gel consistency (mm) | Gelatinization temperature ($^0$C) | Grain length (mm) |
|---|---|---|---|---|---|---|
| Length to width ratio | -0.059 | - | | | | |
| Cooking time (min) | 0.13 | -0.339 | - | | | |
| Gel consistency (mm) | 0.132 | 0.055 | 0.582** | - | | |
| Gelatinization temperature ($^0$C) | -0.674** | -0.072 | 0.355** | -0.269 | - | |
| Grain length (mm) | 0.039 | 0.554* | -0.691** | -0.611** | 0.023 | - |
| Grain width (mm) | 0.166 | -0.383* | -0.348 | -0.698** | 0.004 | 0.509* |

Significant correlation at 5 % level of probability, ** Significant correlation at 1 % level of probability

## 4 Discussions

The study showed that, the $F_{2.3}$ rice families of NERICA 4 x MWUR 4, NERICA 10 x KUCHUM and NERICA 4 x NERICA 1 had higher length to width ratio suggesting that these rice genotypes were slender in shape while NERICA 13 x K45, WAB-56-104 x NERICA 4, CG 14 x NERICA 10 and MWUR 4 x NERICA 4 had medium length to width ratio of between 2.1 and 3.0 implying that they were medium in grain shape. Slender grain shape was also reported in upland rice varieties [20, 21]. Previous studies reported medium grain shape category in local rice varieties [22, 23, 24]. However, the check variety Basmati 370 had slender grain shape with relatively higher length to width ratio than the non-Basmati rice genotypes. Similar findings were reported by Bhonsle and Sellappan [25] and Yadav *et al.,* [26] who studied physico-chemical and cooking properties of some Indian rice varieties of Basmati and non-Basmati. Compared to all the $F_{2.3}$ families evaluated, the check variety Basmati 370 had the highest grain length. Similar findings were observed by Yadav *et al.,* [27] who reported a significantly higher grain length in Indian Basmati rice than non-Basmati varieties.

Rice grain quality depends on physico-chemical properties which are greatly influenced by the genotype of the plant [28]. Determining the physical qualities of rice cultivars is very important because the physical appearance of milled rice is important to the consumer, miller and the marketer [6]. Rice breeders consider grain shape and grain size as the most important rice quality parameters when developing new rice varieties for commercial production because consumer preference for grain shape and size vary from one group of consumers to another [11].

Length to width ratio is important in classification of grain shape. A higher value of over 3 indicate a slender shape, a value between 2.1 and 3.0 reveals a medium shape and a lower value indicate a bold or round shape [29]. Long and slender rice grains are mostly preferred by many consumers and such grains normally fetch higher prices at the international market [30]. Therefore, the physical grain qualities exhibited by NERICA 4 x MWUR 4, NERICA 10 x KUCHUM and NERICA 4 x NERICA 1 can be exploited in a breeding program designed to improve the grain length and shape of local rice cultivars.

This study showed that the $F_{2.3}$ rice families of NERICA 4 x NERICA 1 and MWUR 4 x NERICA 4 showed alkali digestion scale 6 implying that the grain of these rice genotypes dispersed and merged with collar in dilute alkali solution while WAB-56-104 x NERICA 4 showed alkali digestion scale 7 suggesting that the grain completely dispersed and intermingled in dilute alkali solution. The $F_{2.3}$ families of NERICA 10 x KUCHUM showed scale 4 indicating that the grain was swollen, collar complete and wide while NERICA 4 x MWUR 4 showed scale 2- grain swollen while NERICA 13 x K45 and CG 14 x NERICA 10 showed scale 3- grain swollen, collar incomplete and narrow. The $F_{2.3}$ families of CG 14 x NERICA 10, NERICA 4 x MWUR 4, NERICA 13 x K45 and NERICA 10 x KUCHUM had high gelatinization temperatures implying that the starch granules in these genotypes took longer time to start the process of cooking while WAB-56-104 x NERICA 4, NERICA 4 x NERICA 1 and MWUR 4 x NERICA 4 had low gelatinization temperature and cooked fast. Similar findings were also reported [17, 31]. The check variety Basmati 370 had intermediate gelatinization temperature and showed partial disintegration in dilute alkali solution. Similar findings were reported in check rice varieties by Hossain *et al.,* [32]. Low alkali digestion values and high gelatinization temperature were reported in rice germplasm [25, 23]. Previous studies reported alkali digestion scale of 1 to 7 in aromatic rice lines [32, 33, 26]. The cooking and eating characteristics of rice are usually determined by the properties of starch that constitutes 90 % of the milled grain. Alkali spreading value, gelatinization temperature, gel consistency and aroma directly influences the cooking and eating qualities of rice [34]. Gelatinization temperature is the temperature at which all the starch in the rice grain begins the process of cooking and at this stage the starch granules absorb water and irreversibly lose their crystalline nature [35]. Starch in rice grain usually gelatinizes between 55 to 79$^oC$. The gelatinization temperature of rice varieties can be classified as low (55 to 69$^oC$), intermediate (70 to 74$^oC$) and high (75 to 79$^oC$).

The estimate of gelatinization temperature was deduced from the alkali spreading value [36]. The extent of the spreading of the milled rice kernels in a dilute alkali solution is strongly associated with gelatinization temperature [10]. The $F_{2.3}$ families with high gelatinization temperature remained largely unaffected in dilute alkali solution and became excessively soft when overcooked, elongated less and took longer time to cook but those with low gelatinization temperature disintegrated completely in dilute alkali solution and took shorter time to cook. Similar findings were also reported [37, 32, 23]. Therefore, rice genotypes with intermediate alkali digestion value suggested medium disintegration in dilute alkali solution and classified as intermediate gelatinization temperature which is desirable for grain quality [34]. The variation in gelatinization temperature among the rice genotypes could be attributed to higher ambient temperature during grain ripening period that led to formation of starch with high gelatinization temperature [30]. Dela Cruz *et al.,* [7] reported that gelatinization temperature is influenced by environmental conditions such as temperature during grain development.

Based on gel consistency, the $F_{2.3}$ families of WAB-56-104 x NERICA 4, NERICA 4 x NERICA 1 and MWUR 4 x NERICA 4 had high gel consistency suggesting that these $F_{2.3}$ families had soft gel and cooked more tenderly and remained soft even upon cooking while NERICA 13 x K45 had low gel consistency suggesting a hard gel and the grain hardened fast upon cooling. These results are in agreement with the findings of Oko *et al.,* [17], Shejul *et al.,* [20] and Tamu [38]. Gel consistency measures the tendency of the cooked rice to harden upon cooling and it is a good index of cooked rice texture [39]. Gel consistency of rice varieties can be classified into soft gel (61 to 100 mm), medium (41 to 60 mm) and hard gel (26 to 40 mm) [10]. Therefore, these $F_{2.3}$ families with soft gel can be exploited in a breeding program designed to improve the gel consistency of local rice cultivars. Rice varieties with soft gel are mostly preferred by consumers due to their tenderness while eating [17].

In terms of aroma, the $F_{2.3}$ families of MWUR 4 x NERICA 4, NERICA 4 x MWUR 4, CG 14 x NERICA 10 and WAB-56-104 x NERICA 4 had mild aroma while NERICA 10 x KUCHUM, NERICA 13 x K45 and NERICA 4 x NERICA 1 were non-aromatic. Similar results were reported [25, 33]. Futakuchi *et al.,* [35] report moderate aroma in imported rice varieties in Benin. Aroma is an important quality trait that influences the eating qualities and consumer acceptability of a particular rice variety [6]. Aromatic rice varieties command premium prices at the international market [10]. Shayo *et al.,* [37] reported that longer cooking of the rice grains will have a considerable effect on the test and aroma of the cooked rice because some volatile compounds are likely to be lost during cooking. The test panel preferred the check variety Basmati 370 as far as aroma was concerned. Previous research reported similar findings [40]. Sensory analysis helps the consumer to select better rice variety for consumption [23]. Therefore, the results of the sensory test revealed the need for further improvement of this trait (aroma) in the $F_{2.3}$ families evaluated.

Cooking time was strongly correlated with gelatinization temperature and gel consistency implying that rice genotypes with high gelatinization temperature required more cooking time but those with low gelatinization temperature took short time to cook and had soft texture. Similar findings were also reported [17, 26]. Cooking time was negatively correlated with grain length suggesting that an increase in grain length result in reduction in cooking time. Alkali spreading value was negatively correlated with gelatinization temperature suggesting that gelatinization temperature decreases with increase in alkali digestion value. Similar results were also reported [23, 24]. Low value of alkali digestion indicates that the rice kernels are largely unaffected in dilute alkali solution and therefore require high temperature to cook. This is contrary to the findings of Tamu [38] who reported a strong and significant correlation of alkali spreading value with gelatinization temperature. Grain length was strongly correlated with grain width implying that an increase in grain length results in a significant increase in grain width. This is contrary to the findings of Seraj *et al.,* [33] who reported significant and negative correlation of grain length with grain width. Gel consistency was negatively correlated with grain length and grain width implying that rice genotypes with long grain and high grain width have low gel consistency. Correlation analysis is an important tool that helps plant breeders to indirectly select for a farmer preferred trait [33]. Therefore, correlation studies for the physico-chemical traits suggested that efforts aimed at selecting rice varieties with improved cooking quality traits requires a consideration of the physico-chemical qualities of the rice grain [17].

# 5 Conclusion and Recommendation

Out of the 16 segregating populations evaluated, three rice families namely WAB-56-104 x NERICA 4, MWUR 4 x NERICA 4 and NERICA 4 x NERICA 1 had better cooking and physico-chemical quality. The check variety Basmati 370 was outstanding for physical grain quality and aroma compared to the non-Basmati rice genotypes suggesting that Basmati 370 has implication for future breeding. However, there is need to advance these $F_{2.3}$ families to $F_6$ or $F_7$ for further selection in order to ascertain their cooking and eating qualities.

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