Effect of rice variety and location on nutritional composition, physicochemical, cooking and functional properties of newly released upland rice varieties in Ethiopia

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Abstract: The aim of this study was to characterize the newly released different upland rice varieties grown at two representative locations in Ethiopia. This experiment was conducted in factorial design arranged in completely randomized design with three replications. The factors considered were variety (Hidassie, Kokit, NERICA-3, NERICA-4, NERICA-12 and NERICA-13), and growing location (Fogera and Pawe). Collected samples were processed to brown rice and analyzed for selective physical, proximate, cooking, functional, mineral, and color properties. The results showed that the growing location and variety had a significant effect (P ≤ 0.05) on rice quality attributes. The variety Kokit was the most consistent in terms of hectoliter weight, alkali-spreading value, grain weight, amylose, and grain thickness. The mean minimum cooking time of the varieties had ranged from 6.67 to 28.0 min. The gelatinization temperature of upland brown rice varieties varied from 59 to 78.33°C. NERICA-4 grown at Pawe had significantly higher gelatinization temperature (78.33°C) compared to others. The protein content was higher in all the studied varieties grown at Pawe (9.82 to 10.29%) than the varieties grown at Fogera (6.34 to

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PUBLIC INTEREST STATEMENT

In Ethiopia, the research related to rice variety introduction, adaptation and release to the farmers is relatively a recent phenomenon. The rice production and consumption have amazingly increased in the country. Currently, the rice varieties released and being cultivated by the farmers are only based on their yield advantage. However, rice grain quality attributes remain as an important concern for rice breeders, producers, processors, and consumers. The quality characterization of newly released rice varieties is very important for recommendation of rice end uses. Moreover, it is also very important to optimize the process and products which could derive from rice. Hence, this study was conducted to characterize the quality of newly released rice varieties on scientific approach for intended application. Thus, the findings of this research are very crucial for researchers, policymakers, consumers, and processors in field of rice.
The maximum values for manganese (23.52 mg/kg), magnesium (1091.31 mg/kg) and zinc (25.95 mg/kg) were found in Hidassie grown at Fogera. Similarly, the highest Fe content (70.6 mg/kg) was found in NERICA-3 at Pawe. The current findings will be highly useful for the researchers and processors in the field of rice research and development.

**Subjects:** Agriculture & Environmental Sciences; Nutrition; Food Chemistry

**Keywords:** Cooking qualities; functional properties; location; mineral composition; proximate composition; upland rice varieties

### 1. Introduction

Rice (*Oryza sativa L.*) is a vital cereal crop in the world, supplying more than half of the daily calories and proteins for the half of world’s population (Abbas et al., 2011; K. Wang et al., 2015; Y. Zhang et al., 2020). *Oryza sativa* (Asian rice) and *Oryza glaberrima* (African rice) are the two rice species that are massively cultivated globally. However, the indigenous African rice varieties do not receive much scientific attention (Y. Zhang et al., 2020) due to low productivity, the seed scatters easily, the grain is brittle and difficult to mill (Linares, 2002). On the contrary, there are advantages attributed to African rice compared to Asian rice such as resistance to diseases and abiotic stresses (e.g., drought) (Linares, 2002), and they are reported for high protein content and good keeping quality of cooked grains with best suits for weaning food preparations (Gayin et al., 2017; Sarla & Swamy, 2005). In order to optimize the advantages, Asian and African rice were crossed and NERICA (New Rice for Africa) varieties were developed (Fukuta et al., 2012; Zohoun et al., 2018). Most of these varieties were tested, released, and distributed in many African countries including Ethiopia (MoARD, 2014) based on their yield advantage, though their quality aspect did not get emphasis.

Rice production in Ethiopia has progressively increased in recent years. The annual production of rice in Ethiopia was reported as 139,780 tons (FAOSTAT, 2015) and 170,630 tons (FAOSTAT, 2019) in 45,454 ha and 57,576 ha of land, respectively. However, rice grain quality remains an important concern for rice breeders, producers, and consumers in terms of yield, nutritional quality, cooking and eating quality (Custodio et al., 2019).

Determination of rice quality is very important for the improvement of rice and rice-based products (Gayin et al., 2017). Although production season, crop management, harvesting, storage and postharvest operations affects overall quality of rice, growing location, and variety remains the most important determinants physicochemical, nutritional, milling process, and end-use qualities (Danbaba et al., 2011; Laenoi et al., 2018; Monks et al., 2013; Verma & Srivastav, 2017; Yanjie et al., 2018). Rice varieties grown in different locations vary significantly in composition (Abbas et al., 2011), milling, and cooking quality as well as in starch characteristics (Singh et al., 2005). This might be due to the variation in genetic, climatic factor, cultivation method, and soil conditions (Burešová et al., 2010; Mapiemfu et al., 2017; Singh et al., 2005).

The majority of consumers prefer well-milled white rice (Roy et al., 2008, 2011), though it is comparatively poor in micronutrients (Abera et al., 2019). Nowadays, consumers are increasingly concerned about the health benefit of their foods (Zhou et al., 2018). Brown rice is an abundant source of flavonoids and phenolic compounds (C. Zhang et al., 2008), antioxidants, proteins, fats, vitamins, and minerals, mostly concentrated in the germ and the outer layer of the starchy endosperm. Intensive milling of the rice resulted in reduction of these nutrients (Monks et al., 2013). Thus, brown rice is always considered nutritionally superior to milled white rice and is recommended as staple for human health benefits (Sholehah et al., 2020; Xiongsiyee et al., 2018). In recent years, consumer preferences have been shifted towards better quality rice, particularly towards varieties with good eating quality (Custodio et al., 2019).
2019). Each country, and often region, prefers rice with a particular quality traits (Calingacion et al., 2014; Li et al., 2016).

Rice is one of the major cereal crop mainly cooked and consumed as whole grains (Li & Gilbert, 2018). The cooking and eating quality are the most important traits that affect consumers’ acceptability and this is affected by starch composition and characteristics (Bao et al., 2004). Gelatinization property of the rice grain is recognized as one of the most important determinants that could predict the cooking and eating qualities of rice (Bao et al., 2004; Pardhi et al., 2019; K. Wang et al., 2015).

The Ethiopian rice industry is almost negligible as compared to others around the world. Perhaps, its size and quality are barriers to its ability to compete in the international market place. In order to be competent, all concerned bodies should target the high-quality end of niche markets. According to Kibanda and Luiz-Khupi (2007), different quality characteristics of rice are influenced by variety and growing location. But, determinations of the relative magnitude of effects of variety and growing location on physicochemical, proximate, cooking, and functional properties of rice varieties grown at different location of Ethiopia are limited. Therefore, the main objective of this research was to analyze the cumulative effect of the growing environment and varietal differences on various brown rice characteristics.

2. Materials and methods

2.1. Sample collection and experimental materials processing

The newly released six upland rice varieties (Hidassie, Kokit, NERICA-3, NERICA-4, NERICA-12 and NERICA-13) were grown at Fogera (11°58’N and 37°41’E, 1811 masl) and Pawe (11°9’N and 36°3’E, 1050 masl) research centers, Ethiopia. Fogera attains a unimodal rainfall pattern from June to mid-September, mean annual precipitation of 1200 mm and mean annual minimum and maximum temperatures of 13°C and 25°C, respectively. The soil is slightly acidic (pH 5.90) vertisol with a clay content of 71%. The top 20-cm soil horizon contains 3% organic carbon, 52.9 Cmol (+) kg⁻¹ Cation Exchange Capacity (CEC), 0.22% total N, 12.64 ppm available P (Olsen), and 0.93 Cmol (+) exchangeable K·kg⁻¹-soil⁻¹ (Tadesse et al., 2013). Pawe has also a unimodal rainfall pattern from May to October. The mean annual rainfall is about 1500 mm, and the mean annual minimum and maximum temperatures are 16.5 °C and 32.6 °C, respectively. The soil at Pawe is vertisol (clay), and its pH is acidic (< 5.5). The top 30-cm soil horizon contains the total N ranged from 0.13 to 0.16%, available P (Olsen) from 2.26 to 2.86 mg/Kg, organic carbon from 1.85 to 2.6%, and the Cation Exchange Capacity (CEC) from 23 to 30 Cmol/Kg (Getnet et al., 2013).

The type of variety and their parentage used in the present study are presented in Table 1. The recommended fertilizers (69 kg/ha N and 23 kg/ha P₂O₅ at Fogera; 64 Kg/ha N and 46 Kg/ha P₂O₅ at Pawe) were applied. Time of N split application was at planting, tillering, and panicle initiation. All P-fertilizer was applied at planting. Weeding was done three times at tillering, panicle initiation, and late booting stage. Harvesting was done manually using sickles. The grain was stored in polyethylene bag after proper sun drying and threshing.

The laboratory experiments were conducted at Bahir Dar Institute of Technology and JJE analytical testing laboratories. The known weight of the sample (300 g) of paddy rice from each variety was collected at two growing locations. Further, husk was removed using a THU-34A Satake Testing Rice Husker (Satake, Japan) to obtain brown rice. A representative brown rice samples were pulverized using UDY Cyclone Mill (Fort Collins, CO, USA) and passed through a < 1 mm sieve and resulted rice flour was used for analysis. All the samples were stored in air-tight polyethylene bag at 4°C until analysis (Bekele et al., 2012; Horigane et al., 2013).
Table 1. Type of varieties and their parentage used in the present study

| Variety   | Type    | Parentage (Cross combination)           |
|-----------|---------|-----------------------------------------|
| Hidassie  | Japonica| (WAB515-B-16A1:2)                       |
| Kotit     | Indica  | (IRAT-209)                              |
| NERICA-3  | NERICA  | (WAB 56–104/CG 14//2* WAB 56–104)       |
| NERICA-4  | NERICA  | (WAB 56–104/CG 14//2* WAB 56–104)       |
| NERICA-12 | NERICA  | (WAB 56–50/CG 14//2* WAB 56–50)         |
| NERICA-13 | NERICA  | (WAB 56–50/CG 14//2* WAB 56–50)         |

Source: (Fukuta et al., 2012)

2.2. Experimental design
The experiment was conducted in two factors arranged in completely randomized design (CRD). Factor one, variety with six levels (Hidassie, Kotit, NERICA-3, NERICA-4, NERICA-12 and NERICA-13) and factor two, growing location with two levels (Fogera and Pawe) were considered in this study.

2.3. Data collection

2.3.1. Determination of grain physical properties
Hectoliter weight (HLW) was determined on dockage-free samples using a standard laboratory hectoliter weight apparatus (Grain Analysis Computer GAC2100) as described in the AACC (2000) Method no 55–10. Thousand kernel weight (TKW) was determined by carefully weighing thousand randomly selected intact brown rice samples with Mettler Toledo PB 153 electronic balance (GmbH, Greifensee, Switzerland) to an accuracy of 0.0001 g. The axial dimension (length, width and thickness) of both raw and cooked rice kernels were measured on 50 randomly selected intact grains using a digital caliper (Vernier calipers) at ±0.01 mm accuracy. Length–breadth (L/B) ratio was determined by taking the ratio of cumulative length to cumulative average breadth of 50 grains using digital calipers.

Angle of repose was determined using the modified method of Zewdu and Solomon (2007). A tapering hopper made of sheet metal with the top and bottom having a dimension of 150 mm by 150 mm and 50 mm by 50 mm, respectively, and a height of 150 mm was used to measure the angle of repose. At 100 mm from the top, a circular disc of 50 mm diameter was fixed so that enough gaps were left between the hopper wall and disc which allows the seeds to flow through during test. A horizontal sliding gate was providing right below the disc for sudden release of the seed during the test. While testing, seed was filled in the hopper and the horizontal sliding gate was suddenly opened. The height of seed piled on circular disc was measured and calculated using the equation 1:

\[ \theta = \tan^{-1}\left(\frac{h}{r}\right) \]  

where h is the height of piled seed in mm; and r is the radius of the disc in mm.

2.3.2. Determination of proximate composition
The moisture content of rice was determined as described by AACC (2000) Method 44–15 A using laboratory drying oven (DHG–9140A). The crude protein content was estimated from the nitrogen content of rice flour by using micro-Kjeldahl method as stated in the AACC (2000) Method 46–10 with a conversion factor of 5.95. Ash and crude fiber content of brown rice flours were determined according to AOAC approved standard methods 923.39 and 962.09, respectively (AOAC, 2002). Ash content was measured after incineration at 550°C for 8 h. The crude fat content was analyzed gravimetrically by Soxhlet extraction with hexane as solvent. The carbohydrate content (estimated total carbohydrate content) was determined by difference from the analysis of moisture, protein,
ash, and fats. The food energy or calorific value was estimated using equation 2 (Osborn & Voogt, 1978). Amylose content was determined by measuring the blue colour of iodine-binding with amylose using UV-Vis Spectrophotometer (Agilent technology Cary 60 UV-Vis, Malaysia) at 620 nm by taking 100-mg rice flour sample (Adu-Kwarteng et al., 2003). Total amylose content was determined from a standard calibration curve constructed from standard amylopectin (potato, Sigma). Normal maize starch (Merck UniLAB, code 5,871,400) of 28% amylose was used as a control.

\[
\text{FoodEnergy (Kcal/g)} = (\text{Protein} \times 4) + (\text{Fat} \times 9) + (\text{Carbohydrate} \times 4)
\]

(2)

2.3.3. Determination of cooking properties

The minimum cooking time was analyzed using the modified method of Singh et al. (2011). Head rice samples (2 g) were cooked in a beaker containing 20-ml distilled water (1:10) in boiling (98 ± 1°C) water bath. The measurement of cooking time was taken after 10 min and at every min then after few grains of rice were removed and pressed between two glass plates to assess their degree of cooking. The final cooking time was recorded when at least 90% of the grains no longer had an uncooked center. The sample was drained and rinsed with distilled water on a Bucher funnel, allowed to drain for 2 min. The total solid loss was determined by drying an aliquot of cooking water (2 ml) using hot air oven maintained at 105°C in a tarred moisture dish to constant weight. The dry matter content per millilitre of cooking water was regarded as total solids loss (%). Elongation ratio was determined according to the method of Fofana et al. (2011) by randomly selecting cooked rice samples and measured for length and was divided by length of uncooked raw samples. Results were reported as elongation ratio.

Alkali-spreading value was estimated according to the procedure outlined by Cuevas et al. (2010). Ten whole grains of brown rice from each experimental unit were placed and spaced uniformly in petri-dishes containing 10 ml of 1.7% potassium hydroxide solution and incubated at room temperature for 23 h. The degree of spreading was assessed at the 24th h using a seven point scale of 1 to 7, the lower scores indicating higher gelatinization temperature. The level of alkali spreading value classified based on the swelling kernels. The level 6–7 kernels dispersed, merging with collar, and completely dispersed and intermingled considered as low gelatinization temperature (<70°C). In case of 4–5 split or segregated kernels intermediates gelatinization temperature in the range of 70°C to 74°C. If 1–3 kernel were not affected, swollen, and collar complete or narrow indicates high gelatinization temperature (>74°C).

2.3.4. Determination of functional properties

Water absorption index (WAI), water solubility index (WSI), swelling power (SP) of the brown rice flour samples were measured as described by Pardhi et al. (2019). A 2.5 g brown rice flour sample (W_0) was dispersed in 30 ml of distilled water at temperature of 30°C for 30 min, gently stirred during this period, and then centrifuged at 3000 x g for 15 min. The supernatant was poured into a pre-weighed evaporating dish to determine its solid content and the sediment was weighed (W_0). The weight of dry solids was recovered by evaporating the supernatant over night at 110°C (W_ds). WAI, WSI and swelling power (SP) were calculated by equations 3, 4 and 5.

\[
\text{WAI (g/g)} = \frac{W_{ds}}{W_0}
\]

(3)

\[
\text{WSI (g/100g)} = \frac{W_{ds}}{W_0} \times 100
\]

(4)

\[
\text{SP (g/g)} = \frac{W_{ss}}{W_0 - W_{ds}}
\]

(5)
2.3.5. Determination of brown rice color
The color of rice samples was determined using the modified method of Shen et al. (2009) and Adu-Kwarteng et al. (2003). The color of brown rice sample was measured using a portable colorimeter (CM-600D spectrophotometer, Konica Minolta, Japan). The instrument was calibrated with a standard white tile \((L^* = 100.01; \ a^* = -0.01; \ b^* = -0.02)\). Color measurement results were expressed as \(L^*\), \(a^*\), and \(b^*\) color system. During colour measurement, the sample was placed in a glass petri dish. The colour measurements were taken at four locations for each sample, and the average was reported. The spectrophotometer was programmed to report an average of four measurements. The hue angle \((H^o)\) and the chroma \((C)\) were calculated from Equations 6 and 7, respectively.

\[
H^o = \tan^{-1}\left(\frac{b^*}{a^*}\right)
\]

\[
C = \left(\left(a^*\right)^2 + \left(b^*\right)^2\right)^{1/2}
\]

2.3.6. Determination of mineral content
Levels of minerals and trace elements (Mn, Ca, Mg, Fe, Zn & Ni) in the brown rice flour samples were determined by atomic absorption spectrophotometer (Model: 240FS-AA, Agilent, USA) after acid digestion process according to the methods given in AOAC (2000), method number 923.39.

2.4. Statistical analysis
Experimental data were subjected to two-way analysis of variance (ANOVA) and then descriptive statistics for the various grain quality parameters of upland rice varieties grown at Fogera and Pawe were analyzed in triplicate by using PROC GLM procedure of the SAS software version 9.2 (SAS Institute inc., Cary, NC, USA). Significant differences between the means were computed at \(p < 0.05\) using Duncan’s test.

3. Result and discussion
3.1. Physical properties of studied varieties
The physical quality traits of six upland rice varieties grown in the two locations are shown in Table 2. These varieties depicted significant variations \((P < 0.05)\) in their physical quality traits. HLW of the studied varieties ranged from 76.76 to 85.26 kg/hL. HLW was the highest (85.26 kg/hL) for Kokit grown at Fogera, and followed by the same variety (84.36 kg/hL) grown at Pawe, while NERICA-4 (76.76 kg/hL) grown at Pawe was the lowest. A similar result for brown rice was reported by Chapagai et al. (2017), observed a HLW between 75 and 86 kg/hL. The HLW is used for determining the quality and type of packaging material for handling of grains (Falade et al., 2014).

TKW of rice varieties studied in this study were observed in the range of 19.70 to 31.44 g, with NERICA-4 from Fogera depicting the lesser TKW and Hidassie from Pawe the highest. The TKW of the rice varieties had been found in accordance with the reported values as determined previously for different rice varieties (Adu-Kwarteng et al., 2003). This was, however, contradictory to the finding of Shittu et al. (2012) reported a relatively higher TKW ranged from 30.6 to 38.8 g and Chapagai et al. (2017) reported a relatively lower TKW from 13.86 to 22.04 g. TKW is a measurement of seed size and a range of 20–30 g is acceptable. Thus, TKW of all the varieties grown at both locations were acceptable except NERICA-4 grown at Fogera (19.70 g). The TKW below 20 g indicates the presence of immature, damaged, or unfilled grains (Adu-Kwarteng et al., 2003).

Preference for rice grain characteristics vary with consumer groups but rice grain shape has been reported to play a significant role in consumer preferences in different countries and populations (Kesavan et al., 2013). Grain size and shapes are the first rice quality criteria that breeders consider.
Table 2. Effect of location and varieties on the physical quality of upland brown rice

| Locations (L) | Varieties (V)  | HLW (Kg/hL) | TKW (g) | GL (mm) | GW (mm) | GT (mm) | L/B ratio | Angle of repose (degree) |
|---------------|---------------|-------------|---------|---------|---------|---------|-----------|-------------------------|
| Fogera        | Hidassie      | 83.68 ± 0.21<sup>c</sup> | 22.26 ± 0.27<sup>h</sup> | 6.55 ± 0.02<sup>cd</sup> | 2.42 ± 0.09<sup>e</sup> | 1.74 ± 0.03<sup>def</sup> | 2.71 ± 0.10<sup>abc</sup> | 36.55 ± 0.27<sup>p</sup> |
|               | Kokit         | 85.26 ± 0.19<sup>d</sup> | 24.67 ± 0.24<sup>f</sup> | 6.09 ± 0.08<sup>g</sup> | 2.85 ± 0.15<sup>g</sup> | 1.83 ± 0.03<sup>cd</sup> | 2.14 ± 0.14<sup>c</sup> | 34.23 ± 0.18<sup>c</sup> |
|               | NERICA-3      | 79.76 ± 0.23<sup>g</sup> | 23.53 ± 0.39<sup>g</sup> | 6.33 ± 0.08<sup>de</sup> | 2.26 ± 0.06<sup>f</sup> | 1.69 ± 0.06<sup>ef</sup> | 2.79 ± 0.06<sup>de</sup> | 33.19 ± 0.22<sup>de</sup> |
|               | NERICA-4      | 82.68 ± 0.52<sup>d</sup> | 19.70 ± 0.29<sup>g</sup> | 6.45 ± 0.13<sup>e</sup> | 2.27 ± 0.08<sup>f</sup> | 1.67 ± 0.04<sup>f</sup> | 2.84 ± 0.10<sup>de</sup> | 30.78 ± 0.76<sup>de</sup> |
|               | NERICA-12     | 82.48 ± 0.22<sup>de</sup> | 27.09 ± 0.34<sup>g</sup> | 6.84 ± 0.18<sup>de</sup> | 2.5 ± 0.02<sup>de</sup> | 1.77 ± 0.09<sup>e</sup> | 2.73 ± 0.07<sup>abc</sup> | 31.54 ± 0.72<sup>g</sup> |
|               | NERICA-13     | 81.97 ± 0.19<sup>e</sup> | 28.02 ± 0.09<sup>c</sup> | 7.28 ± 0.04<sup>g</sup> | 2.53 ± 0.10<sup>de</sup> | 1.87 ± 0.05<sup>abc</sup> | 2.88 ± 0.11<sup>c</sup> | 31.85 ± 0.63<sup>i</sup> |
| Pawe          | Hidassie      | 81.22 ± 0.16<sup>f</sup> | 31.44 ± 0.32<sup>e</sup> | 7.03 ± 0.13<sup>de</sup> | 2.69 ± 0.11<sup>c</sup> | 1.94 ± 0.01<sup>de</sup> | 2.62 ± 0.12<sup>c</sup> | 31.48 ± 0.57<sup>g</sup> |
|               | Kokit         | 84.36 ± 0.05<sup>bc</sup> | 29.94 ± 0.31<sup>bc</sup> | 6.46 ± 0.11<sup>g</sup> | 3.00 ± 0.02<sup>g</sup> | 1.97 ± 0.04<sup>g</sup> | 2.15 ± 0.03<sup>g</sup> | 29.98 ± 0.68<sup>h</sup> |
|               | NERICA-3      | 80.91 ± 0.20<sup>f</sup> | 26.75 ± 0.08<sup>d</sup> | 7.11 ± 0.34<sup>bc</sup> | 2.49 ± 0.07<sup>d</sup> | 1.89 ± 0.09<sup>bc</sup> | 2.85 ± 0.06<sup>de</sup> | 32.71 ± 0.42<sup>h</sup> |
|               | NERICA-4      | 76.76 ± 0.13<sup>f</sup> | 28.43 ± 0.25<sup>c</sup> | 6.79 ± 0.14<sup>bc</sup> | 2.52 ± 0.06<sup>de</sup> | 1.88 ± 0.04<sup>abc</sup> | 2.70 ± 0.04<sup>bc</sup> | 35.97 ± 0.38<sup>e</sup> |
|               | NERICA-12     | 77.22 ± 0.14<sup>f</sup> | 29.77 ± 0.23<sup>bc</sup> | 7.06 ± 0.29<sup>de</sup> | 2.61 ± 0.05<sup>cd</sup> | 1.92 ± 0.04<sup>abc</sup> | 2.70 ± 0.13<sup>de</sup> | 38.16 ± 0.48<sup>e</sup> |
|               | NERICA-13     | 78.50 ± 0.04<sup>h</sup> | 26.08 ± 0.26<sup>bc</sup> | 6.83 ± 0.37<sup>de</sup> | 2.5 ± 0.02<sup>de</sup> | 1.86 ± 0.04<sup>abc</sup> | 2.73 ± 0.15<sup>de</sup> | 34.02 ± 0.32<sup>cde</sup> |
| P-value (L)   | <0.0001       | <0.0001       | 0.0034  | <0.0001 | <0.0001 | 0.0906  | 0.4108    |                         |
| P-value (V)   | <0.0001       | 0.0171        | 0.0006  | <0.0001 | 0.0171  | <0.0001 | 0.5065    |                         |
| P-value (L*V) | <0.0001       | <0.0001       | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001   |                         |
| CV (%)        | 0.27          | 1.02          | 2.89    | 3.05    | 2.82    | 3.75    | 1.52      |                         |

Values in a column without a common superscript are significantly different (P < 0.05).
All values are given as means of triplicate determinations ± standard deviations.
HLW = Hectoliter weight, TKW = Thousand kernel weight, GL = Grain length, GW = Grain width, GT = Grain thickness, L/R = Length breadth ratio, CV (%) = coefficient of variation.
when developing new varieties for release and commercial production (Fofana et al., 2011). Grain length is more variable than grain width (Anacleto et al., 2015), the size is defined mainly by grain length. Grain shape is defined as the ratio of grain length to grain breadth (Custodio et al., 2019; Graham, 2002). Length to breadth (L/B) ratios are used in the classification of grain shapes, a higher value indicating slender shapes and a lower value indicating medium, intermediate, bold or round shapes. The L/B ratio of the varieties varied from 2.14 to 2.88. The mean L/B ratio was higher (2.88) and lower (2.14) in NERICA-13 and Kokit grown at Fogera, respectively. According to the Codex Alimentarius Commission (1995) classification (2.0–2.9), all the varieties grown at both locations had medium shapes.

The angle of repose of the studied varieties varied from 29.98 to 38.16 degree with an average of 33.37 degree. The angle of repose was more prominent in NERICA-12 (38.16 degree) followed by Hidassie (36.55 degree) grown at Fogera. In this study, Kokit grown at Pawe had the minimum angle of repose (29.98 degree) compared to other studied varieties at both locations.

3.2. Proximate composition of studied varieties

The results on proximate composition of six upland rice varieties from two growing locations are presented in Table 3. The proximate composition of upland brown rice were significantly affected (P < 0.05) by variety and growing location. Grain protein and amylose contents are the two important quality parameters that greatly affect the physicochemical as well as cooking quality of rice (Bagchi et al., 2016). Basically, the rice-to-water weight ratio varies according to its amylose content which had an effect on texture and appearance (Li et al., 2016). Amylose values were significantly different amongst the varieties, where Kokit tends to have highest amylose content followed by NERICA-13. Amylose content of studied brown rice ranged from 13.69 to 25.0% and these are in agreement (13.24 to 24.94%) with the study of Sholehah et al. (2020). Amylose is considered to be one of the most important predictors of the eating quality and pasting behavior of cooked rice and various rice products (Bao et al., 2004). A similar result was reported by Rathin et al. (2010), observed the amylose content for 100 upland rice genotypes ranged from 14 to 25%. Kokit at Fogera had the highest amylose content of 25% followed by the same variety grown at Pawe (24.93%). The amylose content of Kokit did not statistically differ between growing locations.

The varying content of amylopectin in different rice varieties could be attributed to variations in environmental conditions during grain development (Bhat & Riar, 2019). Based on amylose content, rice varieties could be classified as waxy (0–2%), very low (5–12%), low (12–20%), intermediate (20–25%) or high (25–33%) (Li et al., 2016; Zhou et al., 2018). Only Kokit at both location, NERICA-13 at Pawe and NERICA-4 in Fogera were considered as intermediate amylose contained varieties (20–25%), while the rest of the varieties at both location were of low amylose content (<20%). Thus, the intermediate amylose contained varieties are generally most preferred because they cook dry and fluffy retaining their soft texture (Adu-Kwarteng et al., 2003). Rice varieties with low amylose content (below 20%) cook moist and dry sticky (Dipti et al., 2003). In this study, about 66.67% the varieties tested at both locations were of low amylose classification, while 23.33% of the varieties were of intermediate amylose content. A study reported by Monks et al. (2013) showed that, the average amylose content of the brown rice samples (27.1%) was much higher than the current findings (18.9%). Monks et al. (2013) reported increase in amylose by 12% in milled rice than the brown rice due to the presence of the bran components. The high amylose rice demonstrated a faster rate and greater degree of changes in its physicochemical properties than intermediate amylose rice varieties. The low amylose and waxy varieties are often processed in to specialty products (Martin & Fitzgerald, 2002).

Protein, a key factor influencing eating quality of rice (Adu-Kwarteng et al., 2003) was appreciably high (>7%) for all the varieties with the exception of NERICA-3, NERICA-4 and NERICA-13 varieties grown at Fogera. The findings of this study showed that the protein content of rice varieties grown at Pawe (9.82–10.29%; mean of 10.06%) were significantly (P < 0.05) higher than those of rice grown at Fogera (6.34–8.44%; mean of 7.14%) (Table 3). The protein content was the highest and lowest in NERICA-3 (10.29%) and NERICA-13 (9.82%) collected from Pawe, respectively. The amount of protein in rice is relatively low as compared to other cereals like wheat (12.3%), barley (12.8%), and millet (13.4%) and average protein
## Table 3. Effect of location and varieties on the proximate compositions of upland brown rice

| Location | Variety   | Moisture (g/100 g) | Amylose (%) | Protein (g/100 g) | Fiber (g/100 g) | Fat (g/100 g) | CHO (g/100 g) | Energy (kcal) | Ash (g/100 g) |
|----------|-----------|--------------------|-------------|-------------------|-----------------|--------------|--------------|---------------|--------------|
| Fogera   | Hidassie  | 11.43 ± 0.32 c    | 18.51 ± 0.33 c | 7.56 ± 0.29 d   | 2.90 ± 0.02 c   | 3.06 ± 0.14 c | 76.62 ± 0.32 b | 364.24 ± 1.63 cd | 1.33 ± 0.18 a  |
|          | Kokit     | 10.63 ± 0.31 c    | 25.00 ± 0.04 c | 8.44 ± 0.39 c   | 2.59 ± 0.22 g   | 2.97 ± 0.12 cd | 76.69 ± 0.44 b | 367.23 ± 2.18 cd | 1.27 ± 0.09 de  |
|          | NERICA-3  | 9.54 ± 0.21 c    | 15.42 ± 0.35 b | 6.34 ± 0.15 c   | 3.70 ± 0.19 g   | 3.33 ± 0.26 d | 79.53 ± 0.21 a | 373.42 ± 2.29 d | 1.27 ± 0.08 de  |
|          | NERICA-4  | 8.94 ± 0.18 e    | 20.42 ± 0.46 c | 6.53 ± 0.24 c   | 3.30 ± 0.21 c   | 3.53 ± 0.09 a | 79.85 ± 0.45 c | 377.23 ± 0.36 e | 1.16 ± 0.04 c  |
|          | NERICA-12 | 11.18 ± 0.12 a   | 16.39 ± 0.38 b | 7.33 ± 0.26 d   | 4.50 ± 0.15 d   | 2.94 ± 0.09 cd | 77.35 ± 0.33 b | 365.22 ± 0.55 de | 1.19 ± 0.09 bc  |
|          | NERICA-13 | 10.12 ± 0.11 e   | 18.14 ± 0.43 b | 6.63 ± 0.16 c   | 3.15 ± 0.14 e   | 3.19 ± 0.13 bc | 78.97 ± 0.18 a | 371.08 ± 0.79 c | 1.09 ± 0.05 c  |
| Pawe     | Hidassie  | 12.89 ± 0.08 a    | 19.83 ± 0.36 f | 9.91 ± 0.09 de  | 3.15 ± 0.13 e   | 2.65 ± 0.18 e | 73.57 ± 0.31 d | 357.80 ± 0.77 ef | 0.97 ± 0.02 ef  |
|          | Kokit     | 12.19 ± 0.12 b   | 24.93 ± 0.09 g | 10.26 ± 0.30 a  | 2.80 ± 0.11 g   | 1.87 ± 0.11 f | 74.75 ± 0.35 c | 356.84 ± 0.18 h | 0.93 ± 0.02 ef  |
|          | NERICA-3  | 11.58 ± 0.11 c   | 14.43 ± 0.47 b | 10.29 ± 0.23 c  | 2.10 ± 0.21 h   | 2.35 ± 0.22 f | 74.930.17 cd | 362.09 ± 1.02 ef | 0.84 ± 0.03 g  |
|          | NERICA-4  | 11.70 ± 0.16 c   | 13.69 ± 0.35 j | 9.98 ± 0.29 de  | 2.80 ± 0.17 g   | 2.03 ± 0.13 g | 75.26 ± 0.12 c | 359.19 ± 0.67 gp |                |

1.03 ± 0.04**

| NERICA-12 | 11.66 ± 0.09 c | 17.15 ± 0.18 f | 10.11 ± 0.10 de | 3.50 ± 0.26 e | 1.75 ± 0.19 h | 76.92 ± 2.62 b | 363.83 ± 8.60 cd | 0.90 ± 0.03 fg |
| NERICA-13 | 11.69 ± 0.15 c | 23.14 ± 0.29 g | 9.82 ± 0.19 b | 2.10 ± 0.22 h | 2.79 ± 0.12 cd | 74.72 ± 0.26 c | 363.30 ± 1.33 de | 0.97 ± 0.05 ef |
| P-value (L) | <0.0001 | 0.8566 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |<0.0001 |
| P-value (V) | <0.0001 | <0.0001 | 0.0010 | <0.0001 |<0.0009 | 0.0042 | <0.0001 | <0.0001 |<0.0001 |
| P-value (LxV) | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |<0.0001 |
| CV (%) | 1.62 | 1.78 | 2.77 | 5.86 | 5.75 | 1.06 | 0.76 | 6.82 |

Values in a column without a common superscript are significantly different (P < 0.05).
All values are given as means of triplicate determinations ± standard deviations.
CHO = Carbohydrate, CV (%) = coefficient of variation.
content in brown rice is about 8.5% (Mahender et al., 2016). Mohanty et al. (2011) reported 16.41% and 15.27% of crude protein in brown rice of ARC 10,063 and ARC 10,075, respectively, which are much higher than the current findings. The minimum protein content was observed in NERICA-3 (6.34%) grown at Fogera. The protein content of most rice varieties grown in the world have been surveyed by Juliano et al. (1964) and reported between 5 to 17 % with a mean of 10.5%. The variation in protein content of the studied rice varieties could be explained by varietal diversity, growing conditions, and harvesting management. It has been reported that high protein rice is much firmer than low-protein rice (Martin & Fitzgerald, 2002).

The moisture content plays a significant role in determining the shelf life of food products (Bhat & Riar, 2019; Ebuehi & Oyewole, 2008). The moisture content of all rice varieties grown at both locations varied between 8.94 and 12.89% (Table 3), which is lower than the safe moisture content (14%) for the safe storage of rice, although acceptable value of around 12% is recommended for long term storage and to avoid insect infestation and microbial growth (Verma & Srivastav, 2017). The moisture content of the varieties had been found in accordance with the reported values as determined previously for different rice varieties (Verma & Srivastav, 2017). The variations in moisture content had been attributed to the difference in the genotype of cultivars (Bhat & Riar, 2019) and variations in postharvest processing methods. Zheng and Lan (2007) report that moisture content can also influences the milling characteristics and the taste of cooked rice. The highest moisture content was recorded for Hidassie (12.89%) grown at Pawe followed by Kokit (12.19%) grown at Pawe, while the lowest moisture content was recorded for NERICA-4 (8.94%) at Fogera. The results of present study were in line with the finding of Verma and Srivastav (2017) (8.90% to 13.57%). Nearly, similar result was also reported by Sholehah et al. (2020) (10.8 to 13%).

The carbohydrate contents in studied brown rice varieties were ranged from 73.57 to 79.85%, results are in agreement with the study of Sholehah et al. (2020). On the other hand, these values were slightly lower than previously reported in commercial brown rice with exception of NERICA-3, NERICA-4, and NERICA-13 varieties grown at Fogera.

Ash content were significantly (P < 0.05) different among the brown rice samples collected at both locations. Ash content of studied brown rice varieties ranged from 0.84 to 1.33%. The results of the present study were lower than findings of Cáceres et al. (2014) (1.3 to 1.5%). In contrary, Sholehah et al. (2020) reported the ash content ranges from 2.24 to 3.89%, which are much higher than the current finding. Hidassie grown at Fogera had the highest ash content of 1.33%, followed by Kokit (1.27%) and NERICA-3 (1.27%) grown at Fogera, whereas NERICA-3 at Pawe testing site exhibited the lowest ash content (0.84%) (Table 3).

The values of crude fiber content were found significantly (P < 0.05) different among all the studied rice varieties grown at both locations. In this study, the crude fiber content was ranged from 2.1 to 4.5% (Table 3). NERICA-12 grown at Fogera exhibited the highest fiber content (4.5%), followed by NERICA-3 (3.70%) grown at Fogera, NERICA-12 (3.5%) grown at Pawe, and NERICA-4 (3.3%) at Fogera, whereas NERICA-3 and NERICA-13 at Pawe had the lowest crude fiber content (2.1%). Crude fiber content depends on brown rice and harvesting conditions (Lin & Lai, 2011).

Brown rice contains naturally occurring bran oil, which helps in reducing low-density lipoprotein forms of cholesterol (Most et al., 2005). Fat from rice is a good source of linoleic and other essential fatty acids with little or no cholesterol. In the current study, fat contents were significantly different (P < 0.05) among the varieties grown at both locations. The fat content was more prominent in NERICA-4 (3.53%) and followed by NERICA-3 (3.33%) both grown at Fogera. While the lowest fat content was obtained in NERICA-12 (1.75%) grown at Pawe. These results are in line with the observation of Sholehah et al. (2020), reported the fat contents of 21 rice cultivars ranged from 1.45 to 3.65%. Fat content influences the taste of cooked rice because rice with high fat content tends to have tastier (Verma & Srivastav, 2017).
3.3. Cooking properties of studied varieties

Table 4 indicated the interaction of variety by growing location had significant effect (P < 0.05) on the cooking quality parameters of upland rice varieties. Majority of the combinations were significant among each other. Growing environment and variety have been assumed to be important factors affecting the cooking quality of rice. The mean minimum cooking time of brown rice samples varied significantly (Table 4) across the growing location. The cooking characteristics of rice are largely determined by the properties and composition of starch. Amylose and protein content directly influence the cooking qualities of rice (Bagchi et al., 2016). The mean minimum cooking time of the varieties had ranged from 6.67 to 28.0 min. The highest (28.0 min) and lowest (6.67 min) values of cooking time were found in Hidassie and Kokit varieties grown at Pawe, respectively. These values can be used to predict the desired time and quality of rice. Most of the values obtained in this study are similar with the values reported by Singh et al. (2011) except the value recorded in Hidassie, which is characterized by much longer cooking time (28.0 min). This could be attributed to the high gelatinization temperature of Hidassie grown at Pawe. Cooking time between 13.3 and 24.0 min of different rice cultivars had reported by Singh et al. (2005). Easily cooked rice is desirable for energy saving; however, rice grains that are relatively difficult to cook tend to have slower digestion rates, which can be beneficial to human health (Martin & Fitzgerald, 2002). The optimum cooking time of brown rice is much higher than its white counterpart. The study reported by Wu et al. (2016) indicated that the presence of bran significantly increased the optimum cooking time. Except for Hidassie grown at Pawe (28 min), all the other varieties had minimum cooking time between 6.67 and 20.67 min. The observations of this study are accordance with the reports of Batista et al. (2019). All the varieties grown at Fogera had minimum cooking time between 8 and 24 min. Longer cooking durations and harder texture of the cooked rice are the major factors attributing to the lower consumption of brown rice compared to white rice (Chapagai et al., 2017). The cooking time is longer for the brown rice compared to the milled rice (Monks et al., 2013).

As shown in Table 4, the alkali spreading value was significantly different (P < 0.01) among the studied varieties. The average alkaline-spreading value of the varieties ranged from 4.33 to 7.0. The highest (7.0) value was obtained from Kokit grown at both locations, while the least (4.33) value was recorded for NERICA-3 grown at Fogera and NERICA-4 at Pawe. Alkali-spreading value was used to evaluate the gelatinization temperature of brown rice samples from two growing locations. Among the studied varieties nearly 83% of the varieties were classified in to levels 4–5, and the remaining was classed into the levels 6–7, while none of the varieties was belongs to the levels 1–3 (Table 4). The highest alkali-spreading value (levels 6–7) was observed in Kokit grown at both locations. Amylose and associate proteins hampers water entrance in to starch granules and thus hinder the starch gelatinization process (Batista et al., 2019).

Gelatinization temperature, a measure of the time required for cooking, is often measured based on alkali-spreading value. Gelatinization properties of the rice grain are one of the most important determinants that could predict the cooking and eating qualities of rice. The gelatinization temperature of upland brown rice varieties varied from 59 to 78.33°C. NERICA-4 grown at Pawe had significantly higher (78.33°C) gelatinization temperature than the others. The lowest gelatinization temperature was obtained in Kokit (59°C) grown at Pawe, followed by the same variety grown at Fogera (62.0°C).

The maximum cooked grain length was 7.97 mm while the minimum was 6.94 mm. The cooked grain width varied from 2.49 to 3.25 mm. Rathi et al. (2010) reported cooked grain length and cooked grain width for upland rice varieties ranged from 6.5 to 10 mm and 3 to 5 mm, respectively. The grain elongation ratio varied from 0.17 to 1.23 with maximum in NERICA-3 grown at Fogera and the minimum in NERICA-13 grown at Fogera. The results of this study for grain elongation ratio except for NERICA-13 gown at Fogera, is lower than the findings reported by Rathi et al. (2010) which is varied from 1.0 to 1.6.
Table 4. Effect of location and varieties on the cooking properties of upland brown rice

| Location | Variety   | Minimum cooking time (min) | Gelatinization temperature temp (°C) | Alkali spreading value | Cooked grain length (mm) | Cooked grain width (mm) | Cooked grain thickness (mm) | Grain elongation | Gruel solid loss (%) |
|----------|-----------|-----------------------------|--------------------------------------|------------------------|--------------------------|-------------------------|-----------------------------|-----------------|---------------------|
| Fogera   | Hidassie  | 11.00 ± 1.00 \(^{sd}\) | 71.33 ± 1.53 \(^{c}\) | 5.77 ± 0.25 \(^{j}\) | 7.41 ± 0.08 \(^{ef}\) | 2.59 ± 0.01 \(^{f}\) | 1.93 ± 0.03 \(^{de}\) | 0.86 ± 0.07 \(^{a}\) | 5.96 ± 0.18 \(^{e}\) |
|          | Kokit     | 8.00 ± 1.00 \(^{f}\) | 62.00 ± 0.00 \(^{f}\) | 7.00 ± 0.00 \(^{g}\) | 6.94 ± 0.05 \(^{h}\) | 2.98 ± 0.03 \(^{b}\) | 2.01 ± 0.01 \(^{b}\) | 0.86 ± 0.06 \(^{d}\) | 3.78 ± 0.20 \(^{c}\) |
|          | NERICA-3  | 13.0 ± 1.00 \(^{ef}\) | 78.3 ± 0.58 \(^{g}\) | 4.33 ± 0.29 \(^{d}\) | 7.56 ± 0.03 \(^{d}\) | 2.58 ± 0.04 \(^{f}\) | 1.89 ± 0.01 \(^{c}\) | 1.23 ± 0.09 \(^{d}\) | 4.14 ± 0.23 \(^{g}\) |
|          | NERICA-4  | 24.33 ± 2.10 \(^{a}\) | 69.33 ± 0.58 \(^{d,e}\) | 5.83 ± 0.29 \(^{b}\) | 7.35 ± 0.06 \(^{f}\) | 2.49 ± 0.03 \(^{g}\) | 1.81 ± 0.06 \(^{f}\) | 0.90 ± 0.06 \(^{b}\) | 1.71 ± 0.04 \(^{g}\) |
|          | NERICA-12 | 15.00 ± 1.00 \(^{df}\) | 75.33 ± 1.16 \(^{b}\) | 5.17 ± 0.29 \(^{c}\) | 7.70 ± 0.01 \(^{c}\) | 2.77 ± 0.01 \(^{e}\) | 2.03 ± 0.03 \(^{ab}\) | 0.86 ± 0.02 \(^{b}\) | 4.02 ± 0.03 \(^{d}\) |
|          | NERICA-13 | 15.67 ± 2.50 \(^{f}\) | 75.67 ± 1.15 \(^{b}\) | 4.83 ± 0.29 \(^{c}\) | 7.45 ± 0.03 \(^{e}\) | 2.7 ± 0.07 \(^{cd}\) | 2.02 ± 0.04 \(^{b}\) | 0.17 ± 0.02 \(^{f}\) | 2.51 ± 0.02 \(^{f}\) |
| Pawe    | Hidassie  | 28.0 ± 1.00 \(^{d}\) | 70.67 ± 1.16 \(^{cd}\) | 5.83 ± 0.29 \(^{b}\) | 7.97 ± 0.02 \(^{a}\) | 2.94 ± 0.04 \(^{b}\) | 1.97 ± 0.03 \(^{cd}\) | 0.94 ± 0.04 \(^{b}\) | 1.44 ± 0.01 \(^{h}\) |
|          | Kokit     | 6.67 ± 1.15 \(^{e}\) | 59.0 ± 0.00 \(^{c}\) | 7.00 ± 0.00 \(^{a}\) | 7.13 ± 0.04 \(^{g}\) | 3.25 ± 0.04 \(^{e}\) | 2.03 ± 0.01 \(^{ab}\) | 0.67 ± 0.04 \(^{cd}\) | 1.68 ± 0.02 \(^{c}\) |
|          | NERICA-3  | 20.67 ± 1.50 \(^{c}\) | 74.0 ± 0.58 \(^{b}\) | 5.0 ± 0.00 \(^{c}\) | 7.81 ± 0.12 \(^{b}\) | 2.7 ± 0.03 \(^{b}\) | 2.0 ± 0.02 \(^{bc}\) | 0.70 ± 0.09 \(^{c}\) | 1.72 ± 0.01 \(^{a}\) |
|          | NERICA-4  | 19.3 ± 1.53 \(^{c}\) | 78.33 ± 0.60 \(^{d}\) | 4.33 ± 0.29 \(^{d}\) | 7.34 ± 0.01 \(^{f}\) | 2.76 ± 0.09 \(^{c}\) | 2.04 ± 0.04 \(^{ab}\) | 0.55 ± 0.04 \(^{b}\) | 2.20 ± 0.03 \(^{c}\) |
|          | NERICA-12 | 12.67 ± 1.20 \(^{ef}\) | 75.7 ± 0.58 \(^{b}\) | 5.17 ± 0.29 \(^{c}\) | 7.62 ± 0.02 \(^{cd}\) | 2.8 ± 0.04 \(^{c}\) | 2.07 ± 0.03 \(^{c}\) | 0.56 ± 0.03 \(^{c}\) | 2.49 ± 0.10 \(^{c}\) |
|          | NERICA-13 | 9.67 ± 1.50 \(^{df}\) | 68.7 ± 0.58 \(^{d}\) | 5.93 ± 0.12 \(^{b}\) | 7.41 ± 0.01 \(^{ef}\) | 2.6 ± 0.01 \(^{ef}\) | 1.92 ± 0.01 \(^{e}\) | 0.58 ± 0.05 \(^{d,e}\) | 3.38 ± 0.04 \(^{g}\) |
| P-value (L) | 0.2995 | 0.0120 | 0.7396 | 0.0027 | <0.0001 | 0.0120 | 0.0777 | <0.0001 |
| P-value (V) | 0.0002 | 0.0091 | <0.0001 | <0.0001 | <0.0001 | 0.0091 | 0.048 | 0.1169 |
| P-value (L*V) | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0001 | <0.0001 |
| CV (%)     | 9.48     | 1.36   | 4.25   | 0.66   | 1.62    | 1.36   | 7.69   | 3.71   |

Values in a column without a common superscript are significantly different (P < 0.05).

All values are given as means of triplicate determinations ± standard deviations.

CV (%) = coefficient of variation.
The gruel solids loss of upland rice varieties was significantly different among the studied varieties. In this study, the gruel solids loss ranged from 1.44 to 5.96%. The gruel solids loss was observed as highest (5.96%) and lowest (1.44%) in Hidassie grown at Fogera and Pawe, respectively. Other findings reported by Singh et al. (2011) showed that the gruel solids loss in the range of 2.46% to 8.4%, which is much higher than the current findings.

3.4. Functional properties of studied varieties

The result of functional properties showed that there was a significant difference (P < 0.05) in WAI, WSI and swelling power among the varieties (Table 5). WSI of the grain had ranged from 2.75 to 3.6%. Hidassie had the highest WSI (3.6%), followed by NERICA-3 (3.31%) both grown at Fogera. The WAI and WSI of rice based product reported by Pardhi et al. (2019) was ranged from 4.72–7.81 g/g to 5.43–14.32%, respectively. These values are much higher than the current finding for brown rice flour. Brown rice flour hydration properties were affected by both variety and growing location (Table 5). NERICA-12 grown at Pawe had relatively higher mean WAI than the other varieties grown at both the locations, while the lowest values was observed in the same variety grown at Fogera. WAI measures the volume occupied by the gelatinized starch and denatured protein and other components after swelling in excess water maintains the integrity of starch in aqueous dispersion. Water absorption capacity has a major impact on cooking qualities and textural properties of finished product (Wandee et al., 2015).

Swelling power and solubility index provide the evidence of interactions between the water molecules and the starch chains in the crystalline and amorphous regions (AAli et al., 2016). The WAI and swelling power of the studied rice varieties varied from 2.14 to 5.69 g/g and 6.87 to 7.34 g/g, respectively. These variations in WAI and swelling power attributed to the differences in amylose content. The highest swelling power is observed in NERICA-12 (7.34 g/g) and Kokit (7.33 g/g) both grown at Pawe. All varieties except NERICA-12 and Kokit at Pawe, showed statistically significant different (P < 0.05) in swelling power. The low swelling power of NERICA-12 grown at Fogera could be due to its low WAI. When the cooking temperature was constant, the swelling power value remained constant or only slightly changed with different cooking times between 15 and 45 min (He et al., 2018). The swelling power of cereal starches has primarily been reported a property of their amyllopectin content, amylose acts as an inhibitor of swelling, especially in the presence of lipids (He et al., 2018). The swelling power of starch indicates the water absorption ability of starch granules during the starch swelling process (Odejobi et al., 2014).

3.5. Mineral composition of studied varieties

Minerals are well-known essential nutrients and provide a vital role in the effective functioning of the body activity (K. M. Wang et al., 2011). Particularly, Fe and Zn are two most important micronutrients for human body as compared to others. The mineral and trace elements were significantly affected (P < 0.05) by the combined effect of variety and location. A number of studies have explored the significant variation of mineral content among varieties (Huang et al., 2016; Zeng et al., 2010). In the present study, average magnesium content was highest (779.07 mg/kg), followed by calcium (181.28 mg/kg), Fe (18.81 mg/kg), Zn (16.95 mg/kg), Mn (14.7 mg/kg), and Ni (5.21 mg/kg) (Table 6). This variation might be due to varietal characteristics and growing environments. K. M. Wang et al. (2011) reported that the order of six mineral contents in brown rice was Mg > Ca > Mn > Zn > Fe > Se, which can be influenced by cultivars, fertilizer, and geographical conditions.

The analysis result revealed that there was a significant difference (P < 0.05) among varieties for magnesium content. The magnesium content ranged from 504.48 to 1097.67 mg/kg with an average of 779.07 mg/kg. The highest magnesium content was recorded in NERICA-3 (1097.31 mg/kg), followed by Hidassie (1091.31 mg/kg) and NERICA-4 from Fogera. In contrast, the least was observed in NERICA-13 (504.48 mg/kg) from Fogera.
(Table 6). The concentration of calcium was distributed widely in the range of 76.6 to 633.36 mg/kg with an average of 181.27 mg/kg. The highest calcium content was found in NERICA-13 (633.36 mg/kg) from Fogera. This was, however, contradictory to the finding of Verma and Srivastav (2017), reported the magnesium content of 83.5 to 182.45 mg/kg and calcium content of 62.95 to 98.75 mg/kg for milled rice samples which are much lower than the current brown rice samples. Thus, the rice bran plays an important role in determining the mineral composition of rice.

Variation in iron content were significant (P < 0.05) among the varieties. In this study, the iron content of the varieties was found to be in the wide range of 8.95 to 70.6 mg/kg with an average of 18.81 mg/kg (Table 6). The highest Fe content was observed in NERICA-3 at Pawe followed by the same variety grown at Fogera, whereas the least was observed in Kokit grown in Fogera. Except Kokit grown at Fogera, all the varieties showed significantly higher Fe content than the recommended dietary intake for human (10–15 mg/kg) (Mahender et al., 2016). Most of the varieties showed the Fe content below 16 mg/kg with the maximum quantity of 70.60 mg/kg in NERICA-3. According to Norton (2018) the polished rice grains on average contain 2 mg/kg iron, which is much lower than the brown rice. So the consumption of unpolished rice grain may notably reduce the micronutrient deficiency. In the present study, the high Fe content in the brown rice varieties would benefit the consumers and growers of NERICA-3 from both locations.

There was a significant difference (P < 0.05) between varieties for Zinc and Nickel content in the studied varieties. The values for Zinc and Nickel composition of the studied varieties from both locations were ranged from 13.15–25.95 mg/kg to 1.37–9.43 mg/kg, respectively (Table 6). The highest Zinc and Nickel values were obtained in Hidassie (25.95 mg/kg) and Kokit

| Locations | Varieties  | Water absorption index (g/g) | Water solubility index (%) | Swelling power (g/g) |
|-----------|------------|------------------------------|----------------------------|----------------------|
| Fogera    | Hidassie   | 4.39 ± 0.06                   | 3.60 ± 0.27                | 7.15 ± 0.07         |
|           | Kokit      | 4.16 ± 0.08                   | 3.29 ± 0.03                | 7.12 ± 0.08         |
|           | NERICA-3   | 3.75 ± 0.07                   | 3.31 ± 0.18                | 7.06 ± 0.09         |
|           | NERICA-4   | 2.86 ± 0.03                   | 3.10 ± 0.28                | 6.95 ± 0.04         |
|           | NERICA-12  | 2.14 ± 0.07                   | 3.12 ± 0.16                | 6.87 ± 0.06         |
|           | NERICA-13  | 2.44 ± 0.06                   | 3.03 ± 0.27                | 6.9 ± 0.10          |
| Pawe      | Hidassie   | 3.15 ± 0.08                   | 3.06 ± 0.07                | 7.00 ± 0.10         |
|           | Kokit      | 5.48 ± 0.13                   | 2.89 ± 0.05                | 7.33 ± 0.14         |
|           | NERICA-3   | 3.39 ± 0.04                   | 3.0 ± 0.14                 | 7.03 ± 0.06         |
|           | NERICA-4   | 4.63 ± 0.56                   | 3.01 ± 0.11                | 7.18 ± 0.01         |
|           | NERICA-12  | 5.69 ± 0.06                   | 2.87 ± 0.12                | 7.34 ± 0.06         |
|           | NERICA-13  | 2.15 ± 0.09                   | 2.75 ± 0.15                | 6.88 ± 0.10         |
| P-value (L) | 0.0132    | <0.0001                      | <0.0001                    |                      |
| P-value (V) | 0.0023    | 0.0044                       | <0.0001                    |                      |
| P-value (L*V) | <0.0001  | 0.0004                      | <0.0001                    |                      |
| CV (%)    | 1.94       | 5.62                         | 1.15                       |                      |

Values in a column without a common superscript are significantly different (P < 0.05). All values are given as means of triplicate determinations ± standard deviations. CV (%) = coefficient of variation.
Table 6. Effect of location and varieties on the mineral content of upland brown rice

| Locations | Varieties       | manganese (mg/kg) | Calcium (mg/kg) | Magnesium (mg/kg) | Iron (mg/kg) | Zinc (mg/kg) | Nickel (mg/kg) |
|-----------|-----------------|-------------------|-----------------|-------------------|-------------|--------------|---------------|
| Fogera    | Hidassie        | 23.52 ± 0.46<sup>a</sup> | 76.67 ± 3.28<sup>n</sup> | 1091.31 ± 8.88<sup>c</sup> | 14.73 ± 3.08<sup>de</sup> | 25.95 ± 0.74<sup>c</sup> | 1.37 ± 0.13<sup>c</sup> |
|           | Kokit           | 17.62 ± 0.09<sup>c</sup> | 90.67 ± 2.69<sup>g</sup> | 864.03 ± 11.37<sup>c</sup> | 8.95 ± 1.45<sup>n</sup> | 14.71 ± 0.57<sup>de</sup> | 4.85 ± 0.38<sup>c</sup> |
|           | NERICA-3        | 19.21 ± 0.27<sup>b</sup> | 82.34 ± 3.87<sup>n</sup> | 1097.67 ± 17.33<sup>c</sup> | 25.74 ± 0.19<sup>g</sup> | 16.89 ± 0.58<sup>de</sup> | 4.28 ± 0.11<sup>g</sup> |
|           | NERICA-4        | 14.02 ± 0.08<sup>f</sup> | 150.00 ± 4.46<sup>e</sup> | 1018.63 ± 10.9<sup>g</sup> | 18.78 ± 1.13<sup>c</sup> | 13.15 ± 0.59<sup>f</sup> | 3.08 ± 0.07<sup>n</sup> |
|           | NERICA-12       | 12.23 ± 0.34<sup>f</sup> | 163.33 ± 3.88<sup>n</sup> | 818.24 ± 8.96<sup>g</sup> | 15.23 ± 0.09<sup>e</sup> | 14.18 ± 0.71<sup>ef</sup> | 2.98 ± 0.17<sup>h</sup> |
|           | NERICA-13       | 15.28 ± 0.29<sup>e</sup> | 633.36 ± 10.2<sup>o</sup> | 504.48 ± 9.48<sup>h</sup> | 10.18 ± 0.89<sup>de</sup> | 14.71 ± 1.52<sup>de</sup> | 3.55 ± 0.7<sup>j</sup> |
| Pawe      | Hidassie        | 15.85 ± 0.20<sup>b</sup> | 220.39 ± 9.60<sup>c</sup> | 801.76 ± 10.00<sup>g</sup> | 11.22 ± 1.01<sup>de</sup> | 20.63 ± 0.64<sup>b</sup> | 4.82 ± 0.34<sup>ef</sup> |
|           | Kokit           | 8.93 ± 0.08<sup>b</sup> | 152.82 ± 2.86<sup>o</sup> | 679.19 ± 12.20<sup>o</sup> | 10.53 ± 0.49<sup>fh</sup> | 13.20 ± 0.65<sup>bc</sup> | 9.43 ± 0.51<sup>d</sup> |
|           | NERICA-3        | 12.28 ± 0.35<sup>f</sup> | 80.67 ± 1.69<sup>n</sup> | 593.54 ± 9.43<sup>g</sup> | 70.60 ± 1.06<sup>fh</sup> | 17.56 ± 1.09<sup>de</sup> | 6.30 ± 0.6<sup>f</sup> |
|           | NERICA-4        | 13.50 ± 0.30<sup>n</sup> | 123.33 ± 4.43<sup>f</sup> | 639.49 ± 17.80<sup>e</sup> | 12.95 ± 0.99<sup>df</sup> | 17.91 ± 0.74<sup)b</sup> | 6.93 ± 0.16<sup>g</sup> |
|           | NERICA-12       | 12.95 ± 0.08<sup>n</sup> | 128.26 ± 6.79<sup>f</sup> | 598.63 ± 18.50<sup>g</sup> | 13.14 ± 0.07<sup>f</sup> | 17.76 ± 0.58<sup>ef</sup> | 7.05 ± 0.04<sup>c</sup> |
|           | NERICA-13       | 11.07 ± 0.37<sup>f</sup> | 273.45 ± 7.48<sup>o</sup> | 641.86 ± 9.15<sup>f</sup> | 13.65 ± 0.59<sup>de</sup> | 16.77 ± 0.38<sup>de</sup> | 7.88 ± 0.14<sup>h</sup> |
| P-value (L) | <0.0001 | 0.2249 | <0.0001 | 0.0633 | 0.4158 | <0.0001 |
| P-value (V) | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| P-value (L*V) | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| CV (%)      | 1.86 | 3.17 | 1.60 | 6.4 | 4.65 | 6.1 |

Values in a column without a common superscript are significantly different (P < 0.05).
All values are given as means of triplicate determinations ± standard deviations.
CV (%) = coefficient of variation.
Table 7. Effect of location and varieties on the color of upland brown rice

| Location  | Variety | L*   | a*   | b*   | C     | H°    |
|-----------|---------|------|------|------|-------|-------|
| Fogera    | Hidassie| 70.08 ± 0.29<sup>a</sup> | 3.06 ± 0.28<sup>b</sup> | 23.13 ± 0.67<sup>c</sup> | 23.34 ± 0.70<sup>d</sup> | 82.47 ± 0.49<sup>e</sup> |
|           | Kokit   | 68.79 ± 0.61<sup>f</sup> | 3.72 ± 0.46<sup>g</sup> | 23.48 ± 0.61<sup>h</sup> | 23.77 ± 0.55<sup>i</sup> | 80.32 ± 0.09<sup>j</sup> |
|           | NERICA-3| 70.24 ± 0.40<sup>k</sup> | 4.16 ± 0.10<sup>l</sup> | 24.52 ± 0.29<sup>m</sup> | 24.87 ± 0.30<sup>n</sup> | 80.38 ± 0.19<sup;o</sup> |
|           | NERICA-4| 70.84 ± 0.31<sup>p</sup> | 4.67 ± 0.25<sup>q</sup> | 25.45 ± 0.36<sup>r</sup> | 25.87 ± 0.39<sup>s</sup> | 79.60 ± 0.42<sup>t</sup> |
|           | NERICA-12| 70.02 ± 0.08<sup>u</sup> | 4.43 ± 0.24<sup>v</sup> | 23.71 ± 0.18<sup>w</sup> | 24.12 ± 0.12<sup>x</sup> | 79.42 ± 0.65<sup>y</sup> |
|           | NERICA-13| 70.58 ± 0.43<sup>z</sup> | 4.45 ± 0.20<sup>aa</sup> | 24.66 ± 0.16<sup>ab</sup> | 25.06 ± 0.19<sup>ac</sup> | 79.77 ± 0.39<sup>ad</sup> |
| Pawe      | Hidassie| 69.01 ± 0.65<sup>ae</sup> | 4.42 ± 0.04<sup>af</sup> | 24.25 ± 0.44<sup>ag</sup> | 24.65 ± 0.43<sup>ah</sup> | 79.66 ± 0.21<sup>ai</sup> |
|           | Kokit   | 67.40 ± 0.48<sup>aj</sup> | 4.66 ± 0.24<sup>ak</sup> | 24.74 ± 0.25<sup>al</sup> | 25.18 ± 0.29<sup>am</sup> | 79.34 ± 0.42<sup>an</sup> |
|           | NERICA-3| 67.45 ± 0.59<sup>ao</sup> | 4.66 ± 0.56<sup>ap</sup> | 25.67 ± 1.28<sup>aq</sup> | 26.09 ± 1.36<sup>ar</sup> | 79.74 ± 0.74<sup>as</sup> |
|           | NERICA-4| 67.36 ± 0.56<sup>at</sup> | 4.61 ± 0.43<sup>au</sup> | 25.40 ± 0.60<sup>av</sup> | 25.82 ± 0.63<sup>aw</sup> | 79.72 ± 0.88<sup>ax</sup> |
|           | NERICA-12| 68.27 ± 0.36<sup>ay</sup> | 4.16 ± 0.19<sup>az</sup> | 23.58 ± 0.46<sup>ba</sup> | 23.94 ± 0.48<sup>bb</sup> | 80.01 ± 0.28<sup>bc</sup> |
|           | NERICA-13| 70.49 ± 0.50<sup>bd</sup> | 3.40 ± 0.29<sup>be</sup> | 23.44 ± 0.39<sup>bf</sup> | 23.69 ± 0.43<sup/bg</sup> | 81.74 ± 0.60<sup>bh</sup> |

P-value (L*) <0.0001 0.1881 0.1477 0.1422 0.3614
P-value (V) 0.0002 0.0712 0.0003 0.0006 0.0642
P-value (L*V) <0.0001 <0.0001 <0.0001 <0.0001 <0.0001
CV (%) 0.67 7.33 2.29 2.35 0.63

Values in a column without a common superscript are significantly different (P < 0.05).
All values are given as means of triplicate determinations ± standard deviations.
CV (%) = coefficient of variation.

(9.43 mg/kg) grown at Fogera and Pawe, respectively. The Zn content in this finding were in lined with the observation of Xiongsyee et al. (2018) reported the Zn content of 60 upland rice samples from 15.2 to 24.1 mg/kg. The content of Zn in polished rice is an average of about 12 mg/kg, whereas the recommended dietary intake of Zn for human is 12–15 mg/kg (Mahender et al., 2016). The values of the current findings are higher than the recommended threshold level and could be a dietary source for people suffering with Zn deficiency. Nickel was one of the most sensitive parameter under various growing environments. The Ni contents of varieties grown at Pawe (4.82–9.43 mg/kg; mean of 7.07 mg/kg) were significantly higher than those of varieties grown at Fogera (1.37 to 4.85 mg/kg; mean of 3.35 mg/kg) (Table 6).

3.6. Brown rice colour of studied varieties

The L*, a*, b*, C, and H° colour parameters of the brown rice are shown in Table 6. The L* value or brightness/whiteness value of brown rice is an important quality parameter as consumers prefers uniform white colour rice. Variety and growing locations had affected the L*, a*, b*, C* and H° values (Table 7). The average lightness (L*) value of the six brown rice varieties varied markedly (P < 0.05) in the order Kokit (68.09) < NERICA-3 (68.85) < NERICA-4 (69.10) < NERICA-12 (69.14) < Hidassie (69.54) < NERICA-13 (70.54). In this study, the magnitude of the L* value of NERICA-4 grown at Fogera was significantly higher than the others. In contrast NERICA-4 grown at Pawe markedly showed the darkest (lowest L* Value). Kokit, NERICA-3 and NERICA-4 at Pawe were exhibited significantly lower L* values due to level of pigmented external layer of the kernels.

The b* values were found highest in NERICA-3 (25.67) grown at Pawe, followed by NERICA-4 in Fogera. The highest b* values observed for NERICA-3 at Pawe and NERICA-4 in Fogera could be due to its higher phenolic compounds (Bhat & Riar, 2019). Rice colour is determined by a combination of variety, growing environment and post-harvest factors (Ooli et al., 2016). The average chroma of NERICA-3 (26.09) obtained from Pawe was significantly higher and
|          | HLW   | TKW   | LBR   | AR    | PC    | Amylose | MCT   | GTem  | GElog | WSI   |
|----------|-------|-------|-------|-------|-------|----------|-------|-------|-------|-------|
| HLW      |       |       |       |       |       |          |       |       |       |       |
| TKW      | −0.30∗ |       |       |       |       |          |       |       |       |       |
| LBR      | −0.49** | −0.23∗ |       |       |       |          |       |       |       |       |
| AR       | −0.50** | −0.0  | 0.12∗ |       |       |          |       |       |       |       |
| PC       | −0.34∗ | 0.67** | −0.33∗ | 0.22∗ |       |          |       |       |       |       |
| Amylose  | 0.57** | −0.04∗ | −0.68∗ | −0.29∗ | 0.11∗ |          |       |       |       |       |
| MCT      | −0.22∗ | 0.0  | 0.49** | −0.26∗ | −0.02∗ | −0.43** |       |       |       |       |
| GTem     | −0.67** | 0.01 | 0.77** | 0.34 | −0.25∗ | −0.92** | 0.39  |       |       |       |
| GElong   | 0.20∗  | −0.36∗ | −0.19∗ | −0.09∗ | −0.25∗ | −0.01∗  | 0.09∗ | −0.07∗ |       |       |
| WSI      | 0.39∗  | −0.48∗ | −0.01∗ | 0.11∗ | −0.49∗ | −0.09∗  | −0.03∗ | 0.06∗ | 0.34∗ |       |

* Correlation is significant at (p < 0.05).
** Correlation is significant at (p < 0.01).
ns = not significant.

HLW = hectoliter weight, TKW = thousand kernel weight, LBR = length breadth ration, AR = angle of repose, PC = protein content, MCT = minimum cooking time, GTem = gelatinization temperature, GElong = grain elongation, WSI = water solubility index.
indicating more vivid colour. The hue angle (H°) of the brown rice also varied from reddish to the yellowish in the order: NERICA-12 < NERICA-4 < Kokit < NERICA-3 < NERICA-13 < Hidassie. Similar studies done by OOi et al. (2016) showed that the extent of the change in L*, a* and b* varied significantly (P < 0.05) between varieties. The highest hue angle (H°) value was recorded from Hidassie at Fogera followed by NERICA-13 at Pawe while the lowest results were found in Kokit at Pawe.

3.7. Pearson correlation coefficients among some proximate, cooking, and functional properties of upland rice varieties

Amylose content correlated positively with HLW (r = 0.57), but negatively correlated with minimum cooking time, gelatinization temperature and length breadth ratio (r = −0.43, −0.92 and −0.68, respectively) at P ≤ 0.05 (Table 8). Protein content was positively correlated with TKW but negatively with WSI (r = −0.49), which indicates that rice varieties high in protein content and TKW may likely to be low in WSI. Minimum cooking time was positively correlated with gelatinization temperature and length breadth ratio but negatively correlated with amylose. The negative correlation between amylose and cooking time is consistent with reported of Thomas et al. (2013). Gelatinization temperature was positively correlated with length breadth ratio, angle of repose, and minimum cooking time (r = 0.77, 0.34, 0.39, respectively) but negatively correlated with HLW and amylose content (r = −0.67, −0.92, respectively). WSI was positively correlated with HLW and grain elongation (r = 0.39, 0.34, respectively) but negatively correlated with TKW and protein content (r = −0.48, −0.49 respectively).

4. Conclusion

The physicochemical, proximate, cooking, functional, and mineral content of six upland rice varieties grown at Fogera and Pawe location in Ethiopia were examined in this study. There were significant differences (P < 0.05) among the six varieties grown in the two locations for most of the parameters measured. However, the overall qualities exhibited by most of the varieties were in the acceptable ranges of values in case of the important grain quality specifications of rice. A broad range of variation in grain quality traits of the six upland varieties might be attributed to the inherent varietal differences, with emphasizing the complexity of the growing environment. Rice varieties collected from Fogera site are comprised with the highest values in fiber (4.50%), fat (3.53%), ash (1.33%), carbohydrate (79.85%), and amylose (25%) for NERICA-12, NERICA-4, Hidassie, NERICA-4, and Kokit varieties, respectively. The crude protein content was higher in all varieties grown at Pawe (9.82–10.29%) than the same varieties grown at Fogera (6.34–8.44). The largest protein and fiber content recorded in this finding were in NERICA-3 (10.29%) and NERICA-12 (4.50%) at Pawe and Fogera, respectively. The HLW (85.26 kg/hL) and grain length (7.28 mm) were recorded for Kokit and NERICAI-13 grown at Fogera, respectively. Varieties, namely, Hidassie and Kokit grown at Pawe had the highest TKW (31.44 g) and grain width (3.00 mm). It was also noted that Kokit was the most consistent variety in terms of HLW, amylose, alkali-spreading value, grain weight, and gelatinization temperature. The maximum values for manganese (23.52 mg/kg), magnesium (1091.31 mg/kg), and zinc (25.95 mg/kg) were found in Hidassie grown at Fogera. Similarly, the highest values for Fe (70.6 mg/kg) and nickel (9.43 mg/kg) were found in NERICA-3 and Kokit varieties grown at Pawe, respectively. The mean values of Mg were found to be higher in varieties grown at Fogera except NERICA-13 characterized by the lowest value. Among the varieties studied, NERICA-4 at Fogera had the highest L* (lightness) value followed by NERICA-13 at both location. Higher L* values of NERICA-4 at Fogera indicate lighter colour of grains as compared to grains of other varieties. Based on the current study, it could be recommended that all the six upland varieties tested at Fogera and Pawe can plausibly be used for different applications because of their variation in qualities. Finally, the results obtained from the current study can be used as a baseline and indicator for grain quality improvement program.
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References
AACC. (2000). Approved methods of the American association of cereal chemists. American Association of Cereal Chemists.
Abbasi, A., Murtooza, S., Aslam, F., & Khawar, A. (2011). Effect of processing on nutritional value of rice (Oryza sativa). Journal of the Medical Sciences, 6(28), 68–73. https://www.idioi.org/wjms/6(2)/175.pdf
Abera, B., Terefe, B., Boye, K., & Covic, N. (2015). Rice contribution to food and nutrition security and leveraging opportunities for sustainability, nutrition and health outcomes. In P. Ferranti, E. M. Berry, & J. R. Anderson (Eds.), Encyclopedia of food security and sustainability (Vol. 3, pp. 257–263).
Adu-Kwarteng, E., Ellis, W. O., Oduro, I., & Manful, J. T. (2003). Rice grain quality: A comparison of local varieties with new varieties under study in Ghana. Food Control, 14(7), 507–514. https://doi.org/10.1016/S0956-7135(03)00063-X
Ali, A., Wani, T. A., Wani, I. A., & Masoodi, F. A. (2016). Comparative study of the physico-chemical properties of rice and corn starches grown in Indian temperate climate. Journal of the Saudi Society of Agricultural Sciences, 15(1), 75–82. https://doi.org/10.1016/j.jssas.2014.04.002
Anaclet, R., Cuevas, R. P., Jimenez, R., Llorente, C., Nissila, E., Henry, R., & Sreenivasulu, N. (2013). Prospects of breeding high-quality rice using post-genomic tools. Theoretical and Applied Genetics, 128(8), 1449–1466. https://doi.org/10.1007/s00122-015-2537-6
AOAC. (2000). Official methods of analysis (17th ed. ed.). Association of Official Analytical Chemists.
AOAC. (2002). Official methods of analysis (16th ed. ed.). Association of Official Analytical Chemists.
Bagchi, T. B., Sharma, S., & Chattopadhyay, K. (2016). Development of NIRS models to predict protein and amylose content of brown rice and proximate compositions of rice bran. Food Chemistry, 191, 21–27. https://doi.org/10.1016/j.foodchem.2015.05.038
Boo, J., Sun, M., Zhu, L., & Corke, H. (2004). Analysis of quantitative trait loci for some starch properties of rice (Oryza sativa L.): Thermal properties, gel texture and swelling volume. Journal of Cereal Science, 39(3), 379–385. https://doi.org/10.1016/j.jcs.2004.01.004
Batista, C., De, S., dos Santos, J. P., Dittgen, C. L., Colussi, R., Bassinello, P. Z., Elias, M. C., & Vanier, N. L. (2019). August 2018 Impact of cooking temperature on the quality of quick cooking brown rice. Food Chemistry, 286, 98–105. https://doi.org/10.1016/j.foodchem.2019.01.187
Bekele, A., Bultosa, G., & Belete, K. (2012). The effect of germination time on malt quality of six sorghum (Sorghum bicolor) varieties grown at Melkassa, Ethiopia. Journal of the Institute of Brewing, 118(1), 76–81. https://doi.org/10.1002/jib.19
Bhat, F. M., & Riar, C. S. (2015, June). Effect of chemical composition, granule structure and crystalline form of pigmented rice starches on their functional characteristics. Food Chemistry, 297, 124984. https://doi.org/10.1016/j.foodchem.2019.124984
Burešová, I., Sedačková, I., Fáméra, Q., & Lipovský, J. (2010). Effect of growing conditions on starch and protein content in triticale grain and amylose content in starch. Plant, Soil and Environment, 56(No. 3), 99–104. https://doi.org/10.17221/123/2009-pse
Cáceres, P. J., Martínez-Villaluenga, C., Amigo, L., & Frías, J. (2014). Assessment on proximate composition, dietary fiber, phytic acid and protein hydrolysis of germinated Ecuatorian brown rice. Plant Foods for Human Nutrition (Dordrecht, Netherlands), 69(3), 261–267. https://doi.org/10.1007/s11130-014-0433-x
Collingcan, M., Laborte, A., Nelson, A., Resuceccion, A., Concepcion, J. C., Daygon, V. D., Mummm, R., Reineke, R., Dipl, S., Bassinello, P. Z., Manful, J., Sophany, S., Lara, K. C., Boo, J., Xie, L., Loaoo, K., El-hissewy, A., Gayin, J., Sharma, N., Fitzgerald, M., & Rajeswari, S. (2014). Diversity of global rice markets and the science required for consumer-targeted rice breeding. PLoS ONE, 9(1), 1. https://doi.org/10.1371/journal.pone.0085106
Chapagain, M. K., Wan Rosli, W. I., Wan Manan, W. M., Jali, R. A., Karrila, T., & Pinkaew, S. (2017). Effect of domestic cooking methods on physicochemical, nutritional and sensory properties of different varieties of brown rice from Southern Thailand and Malaysia. International Food Research Journal, 24(3), 1140–1147. www.ljft.upm.my/24%20(03)%202017%20pdf.pdf
Codex Alimentarius Commission. (1995). Codex standard for rice. In CODEX STAN 298-1995, 1-10.
Cuevas, R. P., Daygon, V. D., Corpuz, H. M., Nora, L., Reineke, R. F., Waters, D. L. E., & Fitzgerald, M. A. (2010). Melting the secret of rice quality. Functional Plant Biology, 37(5), 439–447. https://doi.org/10.1071/FP09258
Custodio, M. C., Cuevas, R. P., Ynion, J., Laborte, A. G., Velasco, M. L., & Demont, M. (2019). Rice quality: How is it defined by consumers, industry, food scientists, and geneticists? Trends in Food Science and Technology, 92:122–137. September 2017. https://doi.org/10.1016/j.tifs.2019.07.039.
Danbaba, N., Anonye, J. C., Gana, A. S., Abio, M. E., & Ukwunwgu, M. N. (2011). Grain quality characteristics of Ofada rice (Oryza sativa L): Cooking and eating quality. *International Food Research Journal*, 18(2), 629-634. https://www.ifr.upm.edu.my/182010220011/23%20IFRJ-2010-105.pdf

Dipti, S., Bari, M., & Kabir, K. (2008). Grain quality characteristics of some benin rice varieties of Bangladesh. *Pakistan Journal of Nutrition*, 7(4), 242–245. https://doi.org/10.3923/pjn.2008.242.245

Ebuehi, O. A. T., & Oyewole, A. C. (2009). Effect of cooking and soaking on physical, nutrient composition and sensory evaluation of indigenous and foreign rice varieties in Nigeria. *Nutrition and Food Science*, 38(1), 15–21. https://doi.org/10.1108/034658018849772

Falade, K. O., Semon, M., Fadairo, O. S., Oladunjoye, A. O., & Orou, K. K. (2017). Functional and physico-chemical properties of flours and starches of African rice cultivars. *Food Hydrocolloids*, 39, 41–50. https://doi.org/10.1016/j.foodhyd.2013.11.002

FAOSTAT. (2015). Provisional 2015 production indices data. Crop Primary.

FAOSTAT. (2019). Provisional 2019 production indices data. Crop Primary.

Fofana, M., Futakuchi, K., Manful, J. T., Youa, J. B., Dossou, J., & Bleoussi, R. T. M. (2011). Rice grain quality: A comparison of imported varieties, local varieties with new varieties adopted in Benin. *Food Control*, 22(12), 1821–1825. https://doi.org/10.1016/j.foodcont.2011.04.016

Fukuta, Y., Konishio, K., Senno-Nomal, S., Yanagihara, S., Tsunematsu, H., Fukuo, A., & Kumoshiro, T. (2012). Genetic characterization of rainfed upland New Rice for Africa (NERICA) varieties. *Breeding Science*, 62(1), 27–37. https://doi.org/10.1270/jsbbs.62.27

Gayin, J., Abdel-Aal, E. S. M., Manful, J., Bertoff, E., Marcone, M., & Roaige, S. (2017). Physical, cooking and thermal properties of African rice (Oryza glaberrima) and its starch digestibility in vitro. *Lwt*, 75, 481–487. https://doi.org/10.1016/j.lwt.2016.09.023

Getnet, F., Design, E., Menna, A., & Teshome, D. (2012). Response of Yield Components and Grain Yield of Groundnut to Application of Phosphorus and Nitrogen in Northwestern Lowlands of Ethiopia. *Ethiopian Journal of Natural Resources*, 13(1), 11–13. www.researchgate.net/profile/Assefo-Menna/publication/363770490_RESPONSE_OF_YIELD_COMPONENTS_ANDGRAIN_YIELD_OF_GROUNDNU Toe_APPLICATION_OF_PHOSPHORUS_AND_NITROGEN_IN_NORTHERNLOWLANDS_OF_ETHIOPIA/links/5df6b5f92851c577e9ced7cf389b66f/1e6f0.jsViewer?&pdfjsDownload=1&origin=publication_details&previewAsPdf=false

Graham, R. (2003). A Proposal for IRRI to Establish a Grain Quality and Nutrition Research Center. *IRRI Discussion Paper Series No. 44*, 7.

He, M., Qiu, C., Liao, Z., Sui, Z., & Corke, H. (2018). Impact of cooking conditions on the properties of rice: Combined temperature and cooking time. *International Journal of Biological Macromolecules*, 117, 87–94. https://doi.org/10.1016/j.ijbiomac.2018.05.139

Horigane, A. K., Suzuki, K., & Yoshida, M. (2013). Moisture distribution of soaked rice grains observed by magnetic resonance imaging and physicochemical properties of cooked rice grains. *Journal of Cereal Science*, 57(1), 62–64. https://doi.org/10.1016/j.jcs.2012.09.009

Huang, Y., Tong, C., Xu, F., Chen, Y., Zhong, C., & Bao, J. (2016). Variation in mineral elements in grains of 20 brown rice accessions in two environments. *Food Chemistry*, 192, 873–878. https://doi.org/10.1016/j.foodchem.2015.07.087

Juliano, B., Cagampang, G., Cruz, L. J., & Santiago, R. G. (1964). Some physicochemical properties of rice in Southeast Asia. *Cereal Chemistry*, 41(4), 275.

Kesavan, M., Song, J. T., & Sea, H. S. (2013). Seed size: A priority trait in cereals. *Physiologia Plantarum*, 147(2), 113–120. https://doi.org/10.1111/j.1399-3054.2012.01664.x

Kibanda, J. M. N., & Luiz-Khupi, A. (2007). Influence of genetic and genotype X Environment interaction on quality of rice grain. *African Crop Science Journal*, 15(4), 173–182. https://doi.org/10.4314/acsj.v15i4.54455

Laenoi, S., Rerkasem, B., Lordkaew, S., & Prom-u-thai, C. (2018). Seasonal variation in grain yield and quality in different rice varieties. *Field Crops Research*, 221 (June), 350–357. https://doi.org/10.1016/j.fcr.2017.06.006

Li, H., & Gilbert, R. G. (2018). Starch molecular structure: The basis for an improved understanding of cooked rice texture. *Carbohydrate Polymers*, 195:9–17. December 2017. https://doi.org/10.1016/j.carbpol.2018.04.065

Li, H., Prakash, S., Nicholson, T. M., Fitzgerald, M. A., & Gilbert, R. G. (2011). The importance of amylose and amylopectin fine structure for textural properties of cooked rice grains. *Food Chemistry*, 196, 702–711. https://doi.org/10.1016/j.foodchem.2015.09.112

Lin, P. Y., & Lai, H. M. (2011). Bioactive compounds in rice during grain development. *Food Chemistry*, 127(1), 86–93. https://doi.org/10.1016/j.foodchem.2010.12.092

Linares, O. F. (2002). African rice (Oryza glaberrima): History and future potential. *Proceedings of the National Academy of Sciences*, 99(25), 16360–16365. https://doi.org/10.1073/pnas.252604599

Mahender, A., Anandan, A., Pradhan, S. K., & Pandit, E. (2016). Rice grain nutritional traits and their enhancement using relevant genes and QTLs through advanced approaches. *SpringerPlus*, 5(1), 1–18. https://doi.org/10.1186/s40064-016-3744-6

Mapiamfu, D. L., Nándeng, S. A., Ambang, Z., Tang, E. N., Ngome, F., Johnson, J. M., Tonaka, A., & Saito, K. (2017). Physical rice grain quality as affected by biophysical factors and pre-harvest practices. *International Journal of Plant Production*, 11(4), 561–576. https://doi.org/10.22069/jpp.2017.3718

Martin, M., & Fitzgerald, M. A. (2002). Proteins in rice grains influence cooking properties! *Journal of Cereal Science*, 35(3), 285–294. https://doi.org/10.1006/jcrs.2001.0465

MaRD. (2014). Ministry of agriculture and rural development. Crop variety registration. Animal and Plant Health Regulatory Directorate.

Mohanty, A., Marní, B. C., Sharma, S., & Das, A. (2011). Biochemical characterization of two high protein rice cultivars from Assam rice collections. *ORYZA-An International Journal on Rice*, 48(2), 171–174. https://www.indianjournals.com/ijor.aspx?target=ijori.orx&volume=48&issue=2&article=014

Monks, J. L. F., Vanier, N. L., Casaril, J., Berto, R. M., de Oliveira, M., Gomes, C. B., de Carvalho, M. P., Dias, A. R. G., & Elias, M. C. (2013). Effects of milling on proximate composition, folic acid, fatty acids and technological properties of rice. *Journal of Food Composition and Analysis*, 30(2), 73–79. https://doi.org/10.1016/j.jfca.2013.01.009

Most, M. M., Tulley, R., Morales, S., & Lefevre, M. (2005). Rice bran oil, not fiber, lowers cholesterol in humans. *American Journal of Clinical Nutrition*, 81(1), 64–68. https://doi.org/10.1093/ajcn/81.1.64

Norton, G. J. (2018). Rice minerals and heavy metal(coids). In J. Bao (ed.), *Rice Chemistry and technology. AACCI*. Page 21 of 23
Abera Singh, Oli, 171–180. doi.org/10.1016/j.jssas.2016.11.006

Pardi, S. D., Singh, B., Nayik, G. A., & Dar, B. N. (2019). Evaluation of functional properties of extruded snacks developed from brown rice grits by using response surface methodology. Journal of the Saudi Society of Agricultural Sciences, 18(1), 7–16. doi.org/10.1016/j.jssas.2016.11.006

Rathi, S., Yadav, N. S., & Sarmo, R. N. (2019). Variability in grain quality characters of upland cultivated African rice species (Oryza barthii and Oryza glaberrima). Carbohydrate Polymers, 129, 92–100. doi.org/10.1016/j.carbpol.2015.04.035

Wang, K., Wambugu, P. W., Zhang, B., Wu, A. C., Henry, R. J., & Gilbert, R. G. (2015). The biosynthesis, structure and gelatinization properties of starches from rice and cultivated rice of Assam India. Rice Science, 17(6), 330–333. doi.org/10.1016/j.risc.2015.08.015

Roy, P., Iji, T., Okadome, H., Nei, D., Oriksa, T., Nakamura, N., & Shindo, T. (2008). Effect of processing conditions on overall energy consumption and quality of rice (Oryza sativa L.). Journal of Food Engineering, 89(3), 343–348. doi.org/10.1016/j.jfoodeng.2008.05.015

Roy, P., Oriksa, T., Okadome, H., Nakamura, N., & Shindo, T. (2011). Processing conditions, rice properties, health and environment. International Journal of Environmental Research and Public Health, 8(6), 1957–1976. doi.org/10.3390/ijerph8061957

Sarla, N., & Swamy, B. M. (2005). Oryza glaberrima: A source for the improvement of Oryza sativa. Current Science, 95–963. https://www.jstor.org/stable/24110748

Shen, Y., Jin, L., Xiao, P., Lu, Y., & Bao, J. (2009). Total phenolics, flavonoids, antioxidant capacity in rice grain and their relations to grain color, size and weight. Journal of Cereal Science, 49(1), 106–111. doi.org/10.1016/j.jcs.2008.07.010

Shittu, T. A., Olanini, M. B., Oyekanmi, A. A., & Ogeyeaye, K. A. (2012). Physical and Water Absorption Characteristics of Some Improved Rice Varieties. Food and Bioprocess Technology, 5(1), 298–309. doi.org/10.1007/s11947-009-0288-6

Sholehah, L. M., Restanto, D. P., Kim, K.-M., & Handoyo, T. (2020). Diversity, physicochemical, and structural properties of Indonesian aromatic rice cultivars. Journal of Crop Science and Biotechnology, 23(2), 171–180. doi.org/10.1007/s12892-019-0370-0

Singh, N., Kaur, L., Singh Solahi, N., & Singh Sekhon, K. (2005). Physicochemical, cooking and textural properties of milled rice from different Indian rice cultivars. Food Chemistry, 85(2), 235–239. doi.org/10.1016/j.foodchem.2004.02.032

Singh, N., Pali, N., Mahajan, G., Singh, S., & Shevkani, K. (2011). Rice grain and starch properties: Effects of nitrogen fertilizer application. Carbohydrate Polymers, 86(1), 219–225. doi.org/10.1016/j.carbpol.2011.04.039

Tadesse, T., Dechassa, N., Bayu, W., & Gebeeyehu, S. (2013). Effects of farmyard manure and inorganic fertilizer application on soil physico-chemical properties and nutrient balance in rain-fed lowland rice ecosystem. American Journal of Plant Sciences, 4(2), 309–316. doi.org/10.4236/ajps.2013.42041

Zhong, C., Shen, Y., Chen, J., Xiao, P., & Bao, J. (2008). Nondestructive prediction of total phenolics, flavonoid contents, and antioxidant capacity of rice grain using near-infrared spectroscopy. Journal of Agricultural and Food Chemistry, 56(18), 8268–8272. doi.org/10.1021/jf801830z

Zeng, Y., Zhang, H., Wang, L., Pu, X., Du, J., Yang, S., & Liu, J. (2011). Genotypic variation in element concentrations in brown rice from Yunnan landraces in China. Environmental Geochemistry and Health, 33(3), 165–177. doi.org/10.1007/s10653-009-9272-3

Zewdu, A. D., & Solomon, W. K. (2007). Moisture-Dependent physical properties of tef seed. Biosystems Engineering, 96(1), 57–63. doi.org/10.1016/jbiosystemseng.2006.09.008

Effects of drying temperature and moisture content on rice taste quality.
Zhou, X., Ying, Y., Hu, B., Pang, Y., & Bao, J. (2018, March). Physicochemical properties and digestibility of endosperm starches in four indica rice mutants. Carbohydrate Polymers, 195, 1–8. https://doi.org/10.1016/j.carbpol.2018.04.070

Zohoun, E. V., Tang, E. N., Soumanou, M. M., Manful, J., Akissoe, N. H., Bigoga, J., Futakuchi, K., & Ndindeng, S. A. (2018). Physicochemical and nutritional properties of rice as affected by parboiling steaming time at atmospheric pressure and variety. Food Science & Nutrition, 6(3), 638–652. https://doi.org/10.1002/fsn3.600