Nutrient Composition and Predicted Glycemic Index of Rice Varieties from Nigeria

Amaka M. Odenigbo[1,2], Nahemiah Danbaba[3] and Michael Ngadi[1*]

[1]*Department of Bioresource Engineering, McGill University, 21111 Lakeshore Road, Ste-Anne-de-Bellevue, Quebec, H9X 3V9, Canada.*
[2]*Department of Human Nutrition and Dietetics, Michael Okpara University of Agriculture, Umudike, Nigeria.*
[3]*National Cereals Research Institute (NCRI), Badeggi, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author MN designed and supervised the study. Author AMO performed the analysis and wrote the manuscript. Author ND collected the samples. All authors read and approved the final manuscript.

ABSTRACT

Aims: This study aimed to evaluate the nutritional composition, rate of starch digestibility and predicted glycemic indices of selected nine commonly grown rice varieties in Nigeria.
Place and Duration of Study: Samples were collected from Nigeria, analyzed at McGill University, Canada between 2012 and 2013.
Methodology: The samples involved five improved varieties and four local varieties of milled, non-parboiled rice. Predicted glycemic index (pGI) was estimated by *in vitro* enzymatic starch digestion. Proximate nutrients and mineral compositions were determined by standardized methods.
Results: The proximate, mineral composition and starch digestibility varied among samples. The predicted glycemic indices (pGI) were within the range of 66.09 to 73.20 %. *Jamila* had the lowest pGI and starch hydrolysis rate (66.09 % and 0.05 min^{-1},respectively). FARO 52 exhibited significant lowest phosphorus, potassium and magnesium (P<0.05). *Yardass* had significantly highest values for protein (11.59 %) and fat (1.47 %).
Conclusion: The local rice varieties generally, portrayed lower rate of starch digestibility with higher nutritional value compared to improved rice varieties.

Corresponding author: E-mail: Michael.ngadi@mcgill.ca;

1. INTRODUCTION

Rice is a popular staple in Nigeria and there has been a remarkable rise inits consumption. WARDA [1] reported that an average Nigerian, consumes 21 kg of rice per year. In most developing countries, rice accounts for daily supply of 27% energy, 20% protein and 3% fat [2].

Grain of rice is predominantly carbohydrates with protein content of about 7%. This protein content is superior in lysine content compare to other cereals such as wheat, corn, and sorghum [3].

The intake of rice in comparison to other starchy staples has been associated to higher glycemic index [4,5].Glycemic index describes the rate of blood glucose absorption after food consumption [6].

The *in vitro* starchdigestibility procedure has been identified as a simple, inexpensive and useful alternative experimental procedure to *in vivo* method in estimating glycemic response of carbohydrate meals [7-10].

Several studies have reported beneficial role of low glycemic foods in the prevention and dietary management of metabolic diseases [11-13].

There is however, the need to screen the various varieties of available rice for glycemic response. The measurement of starch digestibility in rice is of particular interest and provides vital nutritional information to consumers since rice has become a major dietary source of energy [14,15].

In Nigeria, rice varieties are processed and marketed for consumption either as non-parboiled or parboiled.

Several studies have reported that parboiling - a hydro-thermal postharvest treatment on paddy, elicits lower glycemic responses compared to the non-parboiled rice [16-19].

Other factors that influence glycemic index of rice include geographical location, varieties, preparation of food before consumption and nutritional composition [9,15,20-23].

Studies have demonstrated the influence of various nutritional compositions in food on starch digestibility. These nutrients include; protein content [20, 24], moisture content [25], phosphorus contents [26- 28] resistant starch [15,29].

Literature data portrayed varied values of glycemic index (GI) for non-parboiled rice. A study by Jenkins et al. [30] revealed that white rice had a glycemic index of 83. Miller et al. [31] showed GI values of 64, 83 and 93 for Calrose, Pelde and Doongara white rice, respectively. GI values ranging from 60.1 to 106.3 were reported for milled rice varieties in China [21].

The need for establishing GI of each rice variety in individual countries have been emphasised due to large range of GI variation in geographical location [12,32].

Literature data are available on starch digestibility of rice varieties from Philippines and China. Frei*et al.*[15] reported the glycemic index of six local rice varieties from Philippines. Hu et al. [21] documented the predicted glycemic scores of three leading commercial rice cultivars in China.

Research activities have been documented on local and improved rice varieties in Benin, India and West Africa. Fofana et al. [33] determined the physicochemical and cooking characteristics of imported, improved and local rice varieties consumed in Benin. Sujatha et al. [34] investigated the physicochemical and cooking characteristics of brown and polished, raw and parboiled rice of both local and improved high yielding varieties cultivated in Kannada, India. Lawal et al. [35] studied the starch characteristics of five improved rice varieties (*NERICA, FARO 54*, *FARO 51*, *52* and *FARO 32*) from West Africa.

Despite these numerous studies on different varieties of rice, there is lack of published data on glycemic index of newly improved and indigenous rice varieties in Nigeria. This study therefore aimed to evaluate the predicted glycemic indices, rate of *in vitro* starch digestion and nutritional composition of nine non-parboiled milled rice varieties grown in Nigeria.

2. MATERIALS AND METHODS

2.1 Samples

A total of nine varieties of rice were involved in this study; five improved varieties (*FARO 44, FARO 57, FARO 60, FARO 61*) and four local varieties (*Kwandala, Yardass, Jeep, Jamila*). The selection of these varieties was based on their popularity among rice cultivating communities in the Northern part of the country. Samples were collected directly from the farm. The improved samples were obtained from the Breeding Unit of Rice Research Program, National Cereal Research Institute (NCRI), Badeggi, Nigeria while local rice samples were obtained from crop improvement unit of Kano State Agriculture and Rural Development Agency (KNARDA).

Panicle picking was used in harvesting the samples and afterward sample were dried to 12 % moisture content before manually threshed and cleaned. Samples were dehulled using adehuller (THU 35A, Satake, Engineering Co. Ltd., Tokyo) before milling (McGill mill, Model No. 2, Brookshire, Texas) for 30 seconds. The milled rice grains were then brought to McGill University, Canada for analysis.

2.2 Sample Preparation for Analysis

2.2.1 Raw samples

Grains of the rice samples were individually ground using a coffee grinder (SUMEET Multi Grind, India) and passed through a 60 mesh (0.25 mm) sieve (CETyler, Ontario, Canada). The ground samples were used for nutrient composition analysis.

2.2.2 Cooked samples

Unbroken rice grains (50±0.05mg) were weighed into capped tube and boiled in tap water (5 mL) for 30 min. Samples were homogenized in the cooking water for 1 min using Tissue-Tearor homogenizer (Biospec Products. Inc.) with controlled speed (level 2). The *in vitro*

starch digestibility analysis commenced immediately after homogenization of cooked samples [9,36].

2.3 Proximate Composition

The proximate composition was determined by standard methods of the Association of the Official Analytical Chemists [37]: moisture by drying in an oven at 105°C until constant weight; ash contents by combustion of sample at temperature of 550°C in muffle furnace; Protein by nitrogen determination using LecoNitrogen Analyzer (N x 6.25) while fat determination was by Soxhlet extraction using petroleum ether as solvent. The total carbohydrate content was determined by subtracting the combined weight (in 100 g sample) of protein, fat and ash from the base weight of 100 g.

2.4 Mineral Composition

Ground samples (0.160 ± 0.005 g) were digested at 340 ºC for 3 h in 4.4 ml of a digestion mixture [420 ml sulfuric acid and 350 ml peroxide (30%) with the addition of 14 g of lithium and 0.42 g of selenium]. The digest was diluted to 100 ml with double distilled water.

Concentration of phosphorus was estimated colorimetrically at the wavelength of 880 nm on a flow injector analyzer instrument (QuickChem series 8000, Lachat Instruments, CO, USA). Potassium, magnesium and iron were measured with a flame atomic absorption spectrophotometer (Perkin-Elmer 2380, Norwalk, Connecticut, USA).

2.5 *In vitro* Kinetics of Starch Digestion

A modified *in vitro* method based on the procedure of Goni et al*.* [9] was adopted. The homogenized samples as described above were immediately incubated with 10 ml HCl–KCl buffer (pH 1.5) and 200 µl pepsin solution (100mg /mlHCl-KCl buffer) at 40°C for 1 h with constant shaking. The pH was raised by addition of 200 µl pancreatic α-amylase solution (1.5 mg /10 ml phosphate buffer) and incubated at 37°C for 45 min. Enzyme reaction was stopped with 70 µl Na_2CO_3solution and samples diluted to 25 ml with tris-maleate buffer (pH 6.9). Five (5) ml of pancreatic α-amylase solution (3 U /5 ml tris-maleate buffer) was then added to the sample and incubated at 37°C with constant shaking. Aliquots (duplicate) of 1ml were taken at 30, 90 and 120 min from the samples and placed into boiling water with vigorous shaking for 5 min to inactivate the enzyme reaction. Samples were kept in refrigerator (4°C) after each inactivation until the end of incubation time (120min).

All aliquots were treated with 3 ml of 0.4 M sodium acetate buffer (pH 4.75) and 60µl of AMG (3,300 U/ml) then incubated at 60°C for 45 min with constant shaking.

After incubation, volume was adjusted to 10 ml with distilled water, mixed properlyand centrifuged before transferring 0.1ml aliquots (in duplicate) of the solution intoglass test tubes for glucose measurement.

The glucose released was measured using a glucose oxidase-peroxidase (GOPOD)kit (K-GLOX, Megazyme Bray, Co. Wicklow, Ireland). Absorbance was measured at510 nm wavelength against the reagent blank using a UV- vis spectrophotometer. Glucose was converted into starch by applying the factor of 0.9.Rate of starch digestion was expressed as a percentage of the total starch hydrolysed at different times (30, 90, 120 min). A proposed

equation by Goni et al. [9] was applied in calculation of predicted glycemic index using the 90 min hydrolysis.

$$pGI = 39.21 + 0.803(H_{90})$$

2.6 Statistical Analysis

The starch hydrolysis curves were described with a first order equation:

$$C = C_{\infty} (1-e^{-kt})$$

where, C represents the percentage total starch hydrolyzed at t time; C_{∞} is the equilibrium concentration of percentage total starch after 120 min; K is the kinetic constant and t is the chosen time for the starch hydrolysis.

The kinetic parameters were calculated by a nonlinear regression in MATLAB (Version 7.6.0.324 R2008a, The Math works, Inc., Natick, MA, USA).

Mean values for each variety were compared by a one way analysis of variance (ANOVA) followed by Duncan's multiple range test ($P<.05$).

Independent T-test was performed for differences in nutritional composition and pGI between local and improved rice varieties. The statistical software used was SAS version 4.3 (SAS Institute Inc., 2010, Cary, NC, USA).

UnscramblerX version 10.3 (CAMO Software AS, Oslo, Norway) was used for cluster analysis of variables.

3. RESULTS AND DISCUSSION

The proximate composition of the samples are presented in Table 1. Fat content of samples varied from 0.35 % (*FARO* 60) to 1.60 % (*Yardass*). The values for ash and protein content ranged between 0.23 - 0.80 % and 8.26 to 12.64 %, respectively. *Yardass* had the highest value of protein (12.64 %) and fat (1.6 %) while highest value of ash was found in J*eep* variety (0.80 %). Total carbohydrate content varied between 77.90 to 82.30 % among samples.

Table 1. Proximate composition of non-parboiled rice varieties (% dry matter)

Rice varieties	Fat %	Ash %	Protein %	Total Carbohydrate %
Improved				
FARO44	0.52±0.01[d]	0.45±0.08[bac]	9.59±0.23[ed]	89.44±0.14[ba]
FARO 52	0.54±0.06 [d]	0.23±0.13 [c]	10.05±0.11[c]	89.19±0.04 [b]
FARO 57	1.15±0.04 [b]	0.72±0.06[ba]	9.31±0.11[e]	88.83±0.02[bc]
FARO 60	0.35±0.04 [e]	0.32±0.03[bc]	9.92±0.02[cd]	89.41±0.08[ba]
FARO 61	0.39±0.01 [e]	0.47±0.01[bac]	10.02±0.06[c]	89.12±0.08 [b]
Local				
Jamila	1.10±0.01 [b]	0.66±0.14[bac]	8.26±0.20 [f]	89.99±0.33 [a]
Jeep	0.89±0.02 [c]	0.80±0.12 [a]	10.52±0.35 [b]	87.79±0.48 [d]
Kwandala	0.84±0.04 [c]	0.54±0.07[bac]	10.16±0.09[cb]	88.46±0.13 [c]
Yardass	1.60±0.03 [a]	0.73±0.48[ba]	12.64±0.08 [a]	85.03±0.54 [e]

Mean±SD values with the same superscript letters in a column are not significantly different (P>.05)

These proximate results in our study are consistent with literature data on rice composition. Olembo*et al.* [38] reported mean values of 82% carbohydrate and 0.8% fat in milled rice. A previous study on five major rice varieties (improved and local varieties) in South-Eastern Nigeria reported ranges of 0.5-3.5 % fat, 1.58-6.22 % protein, 0.5-2.0 % ash and 76.92-86.03 % carbohydrate [39].

Since all samples in this present study had similar procedure of dehulling and degree of milling, the observation of varied proximate composition is attributed to varietal differences and different location of planting. Numerous factors influencing nutritive value of crops at different location include soil type, fertilizer application, climate, harvest time, handling and storage of crop before analysis [40,41].

Among all the samples, *Yardass* showed a significantly highest protein (11.59%) and fat (1.47%) content, indicating its nutrient density.

The influence of protein-starch complex in food on starch digestibility reduction had been documented [20,24].

With the current trend of regular and high consumption rate of rice diet, the variability in nutrient density of different rice varieties cannot be overemphasized.

There is variation in mineral composition among samples (Table 2). Phosphorus, potassium and magnesium showed values between 106.07- 259.66 mg/100 g; 213.87- 363.02 mg/100 g; 112.41-324.83 mg/100 g, respectively.

Iron content was generally low among samples (4.21mg/100 g to 40.41 mg/100 g). Lucca et al. [42] reported a very low iron content in milled rice samples.

The values for mineral composition in this present study are comparable with data reported on a Nigerian milled rice 'Ofada' [43]. In the study by Ebuehi and Oyewole [43], the sample had 73.0±8.04 mg/100g phosphorus, 67.0±7.12 mg/100g magnesium and 46.3±2.11 mg/100g iron. Adu-Kwarteng et al. [44] reported ranges of 20.63 -103.75 mg/100g and 100.32-198.97 mg/100g for potassium and phosphorus content in milled rice samples from Ghana.

The varietal differences displayed in potassium content were more pronounced among improved rice varieties than the local varieties. Similar observation was reported by Adu-Kwarteng et al. [44].

It is important to note the low values for phosphorus, potassium and magnesium exhibited by FARO 52 followed by F60. This finding is not surprising, because FARO 52 and F60 had the lowest ash content compared to the other samples in this study (Table 1).

Ash is typically concentrated in the bran of paddy than in the endosperm and there is varietal tendency for some fraction of bran to stick to the rice grain during its removal in milling and polishing processing [44].

This study confirmed varietal influence on proximate and mineral contents of rice varieties. The fact that rice is an important staple food with regular rate of consumption, the selection of nutritionally promising varieties will tend towards appreciable nutrient contribution to daily nutrient requirement.

Table 2. Mineral composition of non-parboiled rice varieties (mg/100 g dry matter)

Rice varieties	Phosphorus	Potassium	Magnesium	Iron
Improved				
FARO44	164.65 ± 0.64^c	266.32 ± 41.42^{cb}	209.57 ± 63.05^{bc}	10.37 ± 8.34^b
FARO 52	106.07 ± 0.24^g	213.87 ± 8.36^d	112.41 ± 1.15^d	5.32 ± 1.24^b
FARO 57	259.66 ± 2.95^a	363.02 ± 30.41^a	266.86 ± 1.42^{ab}	5.92 ± 2.22^b
FARO 60	119.63 ± 0.29^f	215.48 ± 11.26^d	121.32 ± 16.44^{cd}	4.21 ± 0.21^b
FARO 61	141.61 ± 0.09^e	214.69 ± 1.17^d	209.81 ± 0.67^{bc}	10.96 ± 0.75^b
Local				
Jamila	168.45 ± 0.23^c	247.43 ± 2.11^{cd}	252.58 ± 85.77^{ab}	40.41 ± 13.60^a
Jeep	169.57 ± 5.23^c	259.13 ± 7.38^{bcd}	179.75 ± 6.53^{bcd}	16.40 ± 2.96^b
Kwandala	150.06 ± 0.96^d	255.92 ± 8.12^{bcd}	183.49 ± 9.03^{bcd}	8.29 ± 3.08^b
Yardass	220.67 ± 1.89^b	297.65 ± 8.32^b	324.83 ± 32.02^a	10.60 ± 5.93^b

Mean±SD values with the same superscript letters in a column are not significantly different (P>.05)

Starch hydrolysis curves for improved and local varieties are presented in Fig. 1a and Fig. 1b, respectively. Starch hydrolysis pattern are similar for the various varieties with the curves of *FARO 44* and *Jamila* lower than other varieties.

All the improved varieties, except for *FARO 52* seemed to reach maximum hydrolysis (plateau) at 90 min. For the local varieties, *Jeep* displayed earlier plateau before 90 min, *Jamila* and *Yardass* reached maximum hydrolysis at 90 min while *Kwandala* depicted continuous hydrolysis from 90 min which seemed not to be terminated beyond 120 min.
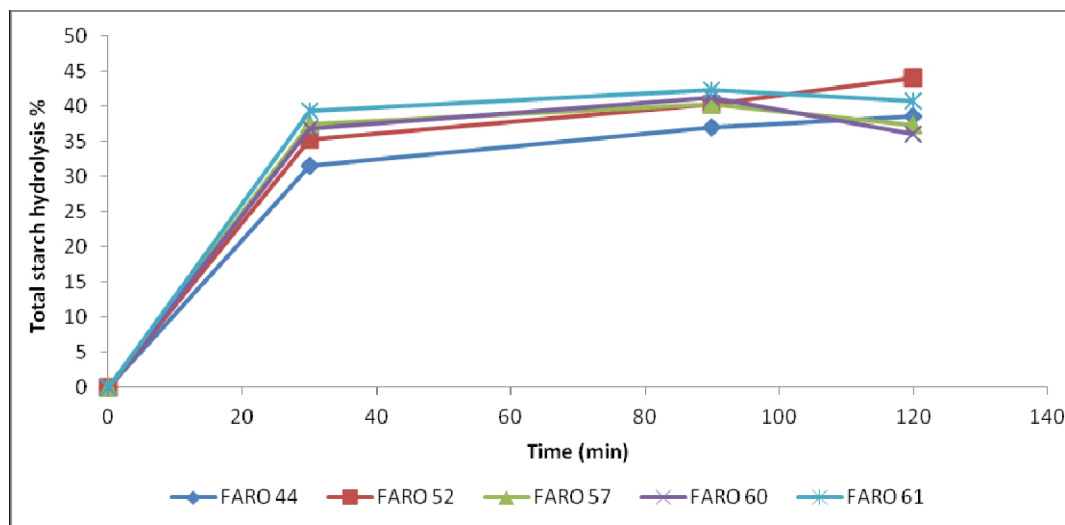
Fig. 1a. Starch hydrolysis curves for non-parboiled improved rice varieties (0-120 min)
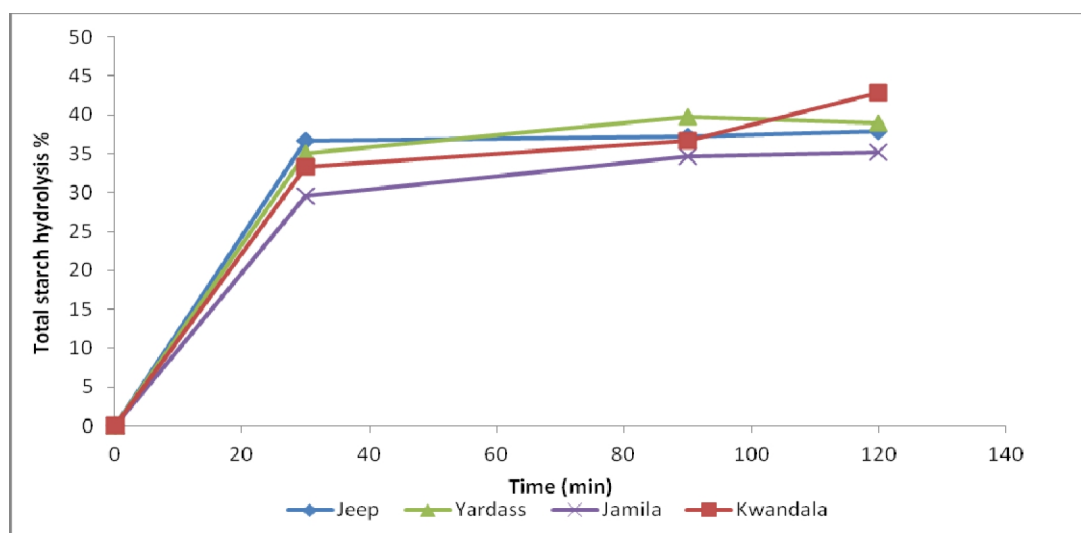

Fig. 1b. Starch hydrolysis curves for non-parboiled local rice varieties (0-120 min)

A non-linear model [9] was applied in obtaining the parameters of starch hydrolysis kinetics (Table 3). Equilibrium concentration (C_∞) which demonstrates the extent of starch hydrolysis when curve reaches a plateau, exhibited a range between 34.44 to 42.31%. Improved rice varieties had relatively higher C_∞ (37.92-42.31%) than local varieties (34.44-38.94%). *Jamila* had lowest C_∞ (34.44%) while highest C_∞ was observed in *FARO 52* (42.31%).

Kinetic constant (k), which is another hydrolysis parameter, showeda range of 0.5 -0.11 m^{-1} among the nine rice samples. The lowest value (0.5 m^{-1}) was also observed in *Jamila* while *FARO 44, FARO 52*, *Kwandala* and *Yardass* had 0.6 m^{-1} k value. The lower values of k in these varieties (particularly in *Jamila*), suggest higher resistance to enzymatic hydrolysisand subsequent reduction in postprandial glycemic response. A starch hydrolysis study on

Jasmine brown rice reported direct influence of both K and C_∞ parameters on GI [45]. This implies that *Jamila* will have a relatively lowest GI since it displayed lowest values of k and C_∞.

The kinetic model for all the varieties showed R-square values closer to 1 (0.9710-0.9932) indicating that the non-linear model [9] applied in this study accounted for more than 97% of the total variation in the data.

The variability in rate and extent of starch digestibility among these samples in our study could then be attributed to the varied nutritional composition of samples. Sitohy and Ramadan [28] reported that phosphorus groups in food reduce starch digestibility by inhibiting the hydrolytic action of α-amylase.

The pGI values varied between 66.09 to 73.20%. This finding is in accordance with literature data on non-parboiled rice varieties. Miller et al. [31] demonstrated GI of 64 – 93% in freshly cooked white rice varieties. In the study conducted by Frei et al. [15], GI values was between 68-109.2% on freshly cooked brown rice samples as compared to 65- 86.7% after 24 h storage. Hu et al. [21] reported 60.1-106.3% GI values for freshly cooked milled rice varieties in China.

The observation of lowest pGIin *Jamila* is not surprising because of its lowest values for K and C_∞. This finding agrees with the report by Jaisut et al. [45] on decreased GI with lower values of K and C_∞in brown rice.

According to Jenkins et al. [13], foods with GI of ≤ 55, 56–69 and ≥70 are classified as low, moderate, and high GI, respectively. In our present study, *FARO 44*, *Jamila*, *Jeep* and *Kwandala* had pGI values of higher than 55 but less than 70% which fall within the moderate glycemic index food.

Although these values are slightly below 70, this result indicates that non-parboiled rice should not be regarded nor classified generally as high glycemic food.

Table 3. Predicted glycemic index, equilibrium concentration, kinetic constant and percentage of total starch hydrolysis at 90 min (H$_{90}$) for non-parboiled rice samples

Samples	pGI (%)	(C$_\infty$)* (%)	(k)* (min^{-1})	H$_{90exp}$ (%)	R^2	RMSE
FARO44	68.92±1.48[d]	37.92	0.06	37.00±1.84[d]	0.9927	1.437
FARO 52	71.52±2.16[abc]	42.31	0.06	40.24±2.69[abc]	0.9823	2.508
FARO 57	71.53±1.51[abc]	38.76	0.11	40.25±1.88[abc]	0.9881	1.879
FARO 60	72.27±1.25[ab]	38.62	0.10	41.17±1.56[ab]	0.9719	2.994
FARO 61	73.20±2.36[a]	41.50	0.10	42.32±2.94[a]	0.9847	2.358
Jamila	66.09±2.07[e]	34.44	0.05	33.47±2.57[e]	0.9717	2.579
Jeep	69.18±0.24[cd]	38.51	0.09	37.32±0.30[cd]	0.9816	2.394
Kwandala	68.37±0.73[ed]	38.68	0.06	36.31±0.91[d]	0.9710	2.961
Yardass	70.46±1.48[bcd]	38.94	0.07	38.91±1.85[bcd]	0.9932	1.448

Mean±SD values within same column followed by same letters are not significantly different (P>.05)
C$_\infty$ = Equilibrium concentration; k = kinetic constant; pGI = Predicted glycemic index
*Parameters of model equation C= C$_\infty$ (1−e^{-kt})
H$_{90exp}$; experimental values for percentage total starch hydrolysed at 90 min

Parameters were compared between the improved and local varieties using the Independent T-test (Table 4). Local varieties showed a significant higher fat (1.01 %) and ash content (0.62 %) compared to the improved varieties (0.53; 0.40 %, respectively). Mean protein of local varieties was found higher than the improved varieties although the difference was not significant at 5 % level (P>.05).

This observation is consistent with previous report on higher protein content in local rice varieties [44].The study by Adu-Kwarteng et al. [44] stated mean protein and ash values of 8.14 and 0.56 % for local varieties of rice in comparison to the breeding lines (7.54 and 0.52 %, respectively).

The mineral composition among the local varieties in our study was found higher than the improved varieties. Only the mean value for iron content was statistically significant (t = -2.37; P< 0.05). The phosphorus, potassium and magnesium composition were not significantly different between the improved and local varieties (P>.05).

Despite the insignificant difference (P>.05), the higher numerical values of ash content in local varieties indicate a general higher mineral composition in local varieties than improved varieties. A similar result was observed in a study between local varieties and breeding lines. Adu-Kwarteng et al. [44]reported significant variation in mean values of potassium (87.05 mg/100 g) and phosphorus (131.74 mg/100 g) among local varieties as compared to the breeding lines (potassium: 85.44 mg/100 g and phosphorus: 167.98 mg/100 g).

The pGI values between local rice varieties and improved varieties were significantly different (t = -4.23; P<.05). Improved varieties had higher pGI (71.49±2.17) than the local varieties (68.52±2.03). This result is in line with the generally higher values of C_∞ and k parameters demonstrated by the improved rice samples (Table 3).

Moreover, the higher proximate and mineral composition among the local varieties supports its lower starch digestibility and predicted glycemic index.

Chung et al. [20] attributed the least GI observed in samples in their study to their greater protein content. Similarly, higher content of phosphorus in study on potato was associated to lower starch digestibility [26,27].

Also, a previous experiment on starch fractions profile of these samples in our laboratory, showed significantly higher resistant starch fraction among local varieties than in the improved varieties [46].

Table 4. Comparison of parameters between improved and local varieties of rice samples

Parameters	Improved rice varieties	Local rice varieties	T-value	P-value
pGI (%)	71.49±2.17	68.52±2.03	-4.23	P<.05*
Fat (%)	0.53±0.28	1.01±0.30	-3.48	P<.05*
Ash (%)	0.40±0.17	0.62±0.20	-2.56	P<.05*
Protein (%)	8.91±0.30	9.50±1.53	-1.19	P>.05
Carbohydrate (%)	81.27±0.66	80.21±2.03	1.55	P>.05
Phosphorus (mg/100g)	144.28±52.45	161.83±25.84	-0.86	P>.05
Potassium (mg/100g)	232.04±57.89	242.08±19.71	-0.47	P>.05
Magnesium (mg/100g)	167.67±59.87	214.96±66.84	-1.58	P>.05
Iron (mg/100g)	6.70±3.74	17.29±13.60	-2.37	P<.05*

* Difference is significant at the 5 % level (2-tailed).

The visual relationship of samples in studied parameters was displayed by average linkage clustering using squared Euclidean distance (Fig. 2a -2c).

Dendrogram of proximate nutrients (Fig. 2a) grouped the samples into three distinct clusters. Only Yardass was grouped in a cluster which appeared to be distinct from the other eight samples. The second cluster similarly comprised only Jamila sample while the remaining samples (F44, F52, F57, F60, F61, Jeep and Kwandala) were clustered closely. The third cluster was further grouped into sub clusters. The first sub cluster comprised Jeep and Kwandala while other sub clusters consisted the improved varieties. This observation indicated similarity in proximate composition among improved rice varieties. It is noteworthy that Yardass showed very high protein and fat contents with low carbohydrate where as Jamila had relatively high carbohydrate with low protein content (Table 1).

Fig. 2b showed three distinct clusters for mineral composition. The first cluster comprised samples with high values for phosphorus, potassium and magnesium (Yardass and F57). Samples with moderate mineral contents were grouped in the second cluster (F44, F61, Jeep, Kwandala, Jamila). This second cluster had further sub clusters. The third cluster comprised samples with low mineral values (F52 and F60).

The dendrogram of starch digestibility (Fig. 2c) demonstrated that the cluster consisting only Jamila, appeared to be distinct from all other samples in this study. Jamila had low starch hydrolysis and predicted glycemic index (Table 3). The second cluster of starch digestibility grouped samples with higher predicted glycemic index and increased rate of starch hydrolysis (F52 and F61). The third cluster comprised the remaining six samples. Samples within cluster 3 were further grouped into two sub clusters. The first sub cluster comprised Yardass, F57 and F60. The second sub cluster comprised F44, Jeep and Kwandala. Within these sub clusters, F57 and F60 as well as F44 and Jeep appeared to be more closely related to each other in starch digestibility.

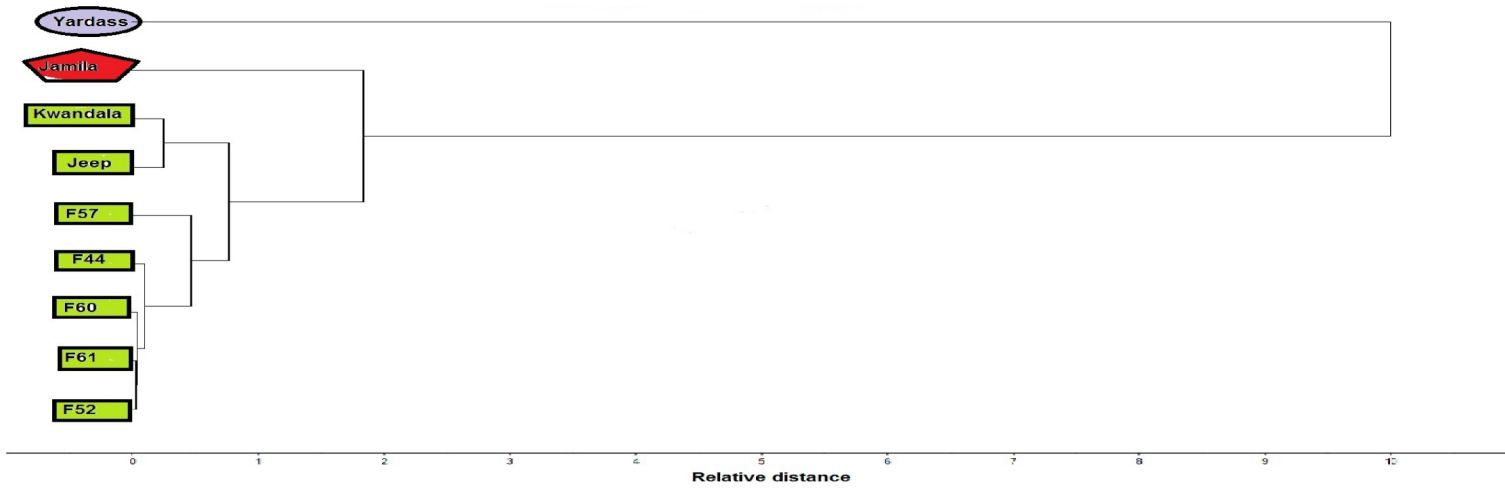This result of cluster analysis was comparable to the ANOVA analysis on studied variables.

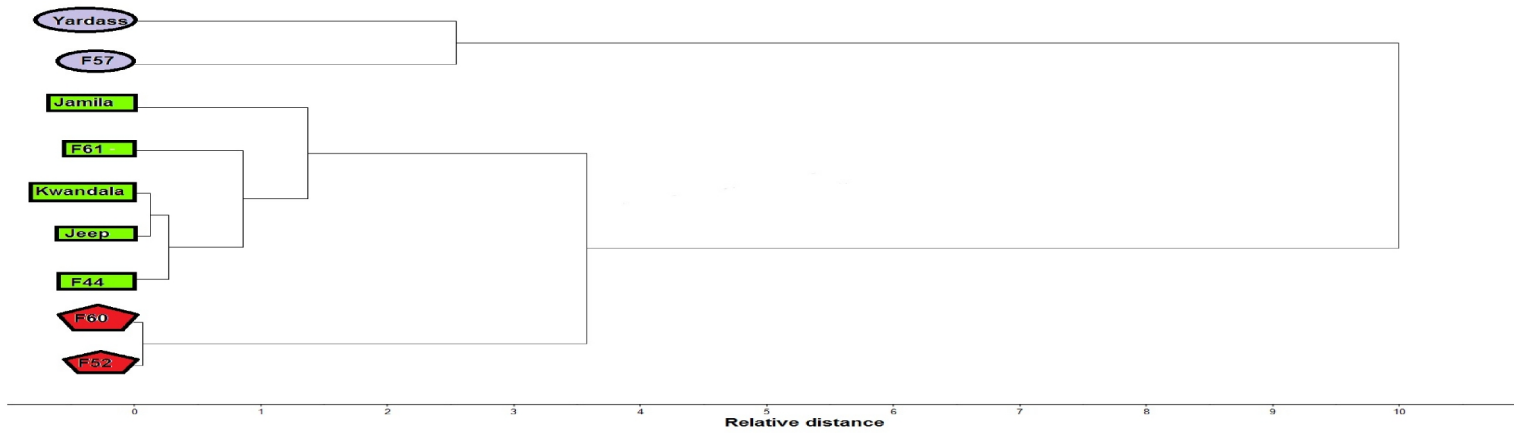**Fig. 2a. Dendrogram of proximate nutrients**

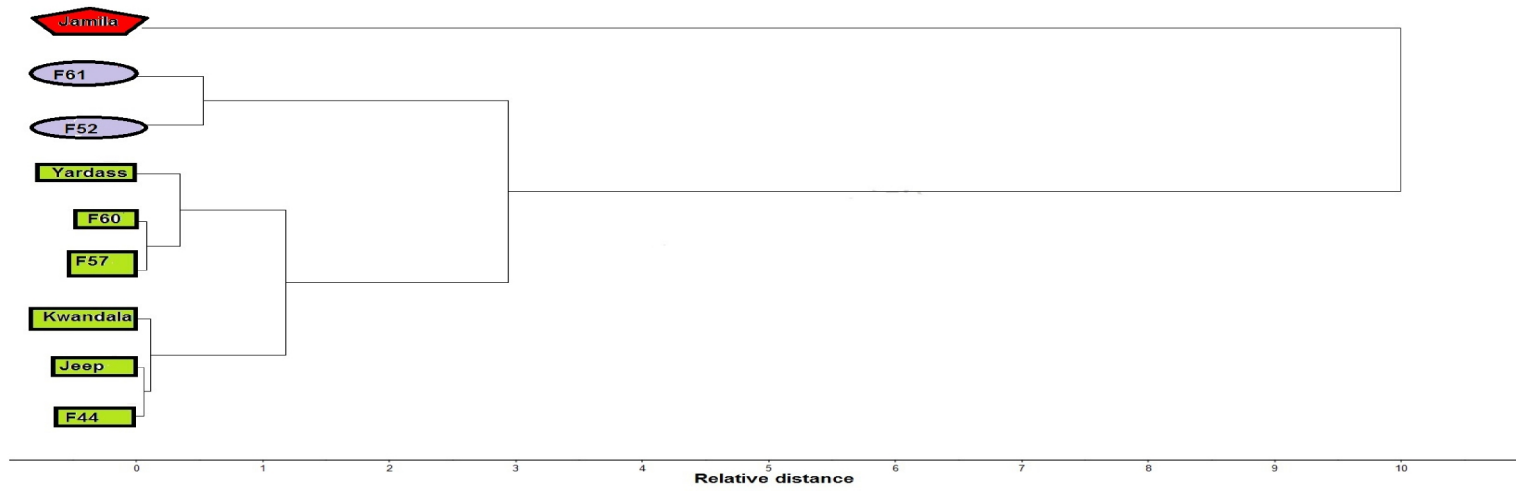**Fig. 2b. Dendrogram of mineral composition.**

Fig. 2c. Dendrogram of starch digestibility

4. CONCLUSION

Our study demonstrated varied levels of nutritional composition and starch digestibility rate among local and improved milled rice varieties. The local rice varieties had lower mean levels of pGI, starch hydrolysis rate with higher protein, ash, fat and mineral contents compared to improved rice samples. The values for pGI among samples indicated that non-parboiled rice varieties should not be generally regarded as high GI food.

This data will provide useful nutrition information for rice product development and in the selection of local varieties for breeding newly improved rice.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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