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Physicochemical Characterization of Four Commercial Rice Varieties in Ghana

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Abstract: This study evaluated the physical characteristics, proximate and mineral composition, and functional properties of four commercial Ghanaian rice varieties compared to two imported rice brands to provide data for quality improvement. Imported brands were significantly different ($p<0.05$) from local varieties in grain dimensions and colour. Local varieties had higher mean values for grain width (2.21-2.26 mm), 1000-grain weight (19.5-22.3 g) and bulk densities (0.87-0.91 g/mL). Physical properties that negatively affect grain quality - brokens (13.60-32.70%); moldiness (0.89-22.3%); chalkiness (0.17-0.44%); and immature grains (0.05-0.33%) - were also higher. However, the local varieties were nutritionally superior to the imported brands, having higher iron (5.0-8.2 mg/kg) and phosphorous (1166-1374 mg/kg) contents. All the samples were non-waxy rice types with high gelatinization temperatures (83.8-88.2ºC), soft gels (66-98 mm) with low to intermediate amylose content (15.9-22.7%). The competitiveness of locally grown rice can be enhanced by improving physical quality and adopting a marketing strategy that emphasizes the nutritional quality and suitability for specific foods.

Key words: Imported, local, marketing, nutritional, quality

INTRODUCTION

Rice (*Oryza sativa* L.) has become a staple in Ghana and much of West Africa where it serves as an important convenience food for urban consumers (Tomlins *et al.*, 2007). At a per capita consumption of 15.1 kg/annum and an estimated national consumption of 353,300 metric tonnes, rice registered the highest deficit (210,700 metric tonnes) on the domestic food supply and demand position for Ghana in 2008 (Ayittey and Banini, 2009).

Rice is used in a wide range of food products in Ghana; the most common include jollof rice, rice balls, rice porridge, fried rice and plain-cooked rice. The various rice products are fundamentally different in their appearance and characteristics: plain rice is boiled rice with each rice grain still whole and independent of the other, while '*rice balls*' and '*rice porridge*' may have the rice grains completely or partially broken in the product.

Although rice forms a major part of the Ghanaian diet, locally grown rice is not patronized because of its variable quality. Several factors account for the variability in rice quality – the most prominent factors are the poor sensory and physical qualities (Tomlins *et al.*, 2005). These quality defects arise not only from inappropriate post-harvest handling, but also from poor planting materials and poor agronomic practices (Gayin *et al.*, 2009). Perhaps if the quality of local rice is improved and made comparable to that of the imported rice, then it will be possible to increase the market for local rice.

The Ghana Rice Inter-Professional Body (GRIB) is pursuing a program of introducing better-quality rice varieties to local farmers in order to improve the competitiveness and patronage of locally grown rice. Consequently, some commercial varieties have been released by this national initiative on to the Ghanaian market. But, the patronage of these varieties in the urban centers is not encouraging due to some of the aforementioned reasons.

Previous studies in Ghana focused on the nutritional value of some rice processing by-products. They also conducted quality and sensory evaluations of varieties that are on the verge of being released in Ghana (Gayin *et al.*, 2009; Tomlins *et al.*, 2007; Adu-Kwarteng *et al.*, 2003; Amissah *et al.*, 2003; Manful *et al.*, 1996). There is, however, the need to collect information on the physicochemical characteristics and to make a more direct comparison of locally grown and imported rice as a basis for the improvement of local rice and enhancement of its market competitiveness. This study therefore evaluated the variations in the physical, chemical and rheological characteristics of four local commercial rice varieties in Ghana to provide information for rice breeders for consideration in future breeding programs.

MATERIALS AND METHODS

Samples: Four local varieties and two imported brands of rice were evaluated for their physicochemical

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characteristics in 2009 in Ghana at the CSIR-Food Research Institute (Accra, Ghana) and the International Rice Research Institute (Los Banos; Laguna, The Phillipines). Three of the local varieties (*Marshall*, *Ex-Baika* and *Jasmine 85*) were grown under the same environmental and fertilizer regimes. The other local variety - *Ex-Hohoe* - was cultivated under rain-fed conditions. The two imported rice brands used as controls - *Sultana* and *Royal Feast* - were obtained from a retail outlet in Accra based on their high consumer patronage, as revealed by a preliminary consumer survey of local and imported aromatic rice varieties sold on the market (Diako *et al.*, 2010).

About 500 g (in triplicate) of paddy of each of the locally grown rice varieties (moisture content: 11.0-12.3%) were dehusked in a Satake Testing Rice Husker (THU-358, Satake Co. Ltd., Tokyo, Japan). The brown rice obtained was then polished in a Single Pass Rice Pearler (BS08A, Satake Co. Ltd., Tokyo, Japan), with the degree of whiteness set to 'medium'. Samples were sealed in transparent polythene bags (8×13.5, Poly Products (GH) Ltd.,) prior to analysis.

Physical measurements: The physical characteristics measured for each sample were: Grain size and shape (FAO, 1975); 1000-grain weight (Dorsey-Redding *et al*., 1991); total milling recovery; L, a, b colour parameters; physical examination for amounts of immature, mouldy, discoloured, red rice, paddy, chalky grains and stones (WARDA, 1995); level of brokens (Adu-Kwarteng *et al*., 2003) and bulk density (Singh *et al.*, 2005).

Chemical analyses: Chemical tests conducted were gel consistency (Perez, 1979); alkali spreading value (Bhattacharya and Sowbhagya, 1972); amylose content (Blakeney *et al*., 1994); protein content (AOAC, 2000) and mineral analysis - iron, phosphorous, and calcium contents using X-ray fluorescence spectroscopy using the following procedure: Rice grains (7 g) were ground by adding tungsten balls in a paint shaker (Fast and Fluid Management SO 400 Service; The Netherlands) for 1 h at speeds of up to 720 rpm. The fine ground rice flour (5 g) was pelleted in a stainless steel mould at a pressure of 10 t. The pellet was then placed in a Panalytical MiniPal 4 X-Ray Fluorescence and run for 30 min. Measurement was based on a standard calibration curve of the National Institute for Standards and Technology, USA, using rice flours of known micronutrient concentrations.

Rheological properties: The pasting properties of rice flour slurries (~3.0 g, corrected to 12% moisture, in 25.0 mL deionized water) were measured using the Rapid Visco Analyzer (Model 3D, New Port Scientific, Australia). The Rapid Visco Analyzer was run according to the profile in Table 1.

Table 1: Rapid Visco Analyzer (RVA) profile used

Time (hh:mm:ss)	Function	Value
00:00:00	Temperature	50ºC
00:00:00	Speed	960 rpm
00:00:10	Speed	160 rpm
00:01:00	Temperature	50ºC
00:04:48	Temperature	95ºC
00:07:18	Temperature	95ºC
00:11:06	Temperature	50ºC

Idle temperature: 50±1ºC
End of test: 12 min, 30 sec
Time between readings: 4 sec
Shuey and Tipples (1980)

Data analysis: Minitab (version 14) was used for statistical analysis and graphical presentation of the data. ANOVA was used to test for significant differences between means. A multiple range test (Tukeys Honestly Significant Differences) was conducted at a level of significance of $p<0.05$. Cluster analysis (cluster observations) was carried out to determine rice varieties with similar characteristics. Principal Component Analysis (PCA) was used to determine any patterns and to explore the relationships between the various parameters and the rice samples.

RESULTS AND DISCUSSION

Physical quality characteristics of rice types: This study showed that the imported rice types had high mean grain lengths and low grain widths, resulting in higher length/width (L/W) ratios. The opposite was the case for the locally grown rice types (Table 2). Optimum cooking time correlates positively with width but negatively with cohesiveness of rice grains (Mohapatra and Bal, 2006). The imported rice type will, therefore, cook faster and be suitable for rice dishes that require rice grains to remain whole and independent of each other like plain-cooked rice and fried rice.

The local varieties generally had bolder grains, with their widths ranging from 2.21 to 2.26 mm compared with 1.96 mm for the imported varieties. All varieties were long grain except *Ex-Hohoe* according to the FAO (1975) standard for grain size classification. However, three varieties - *Ex-Baika*, *Ex-Hohoe* and *Marshall* - were medium-shaped grains according to the same standard; while the rest were slender-shaped. The imported brands had low 1000-grain weights (TGWs). Values of TGW between 20 and 30 g are considered good while those less than 20 g could be indicative of the presence of immature, damaged, and unfilled grains (Adu-Kwarteng *et al.*, 2003). However, other researchers associated low TGWs to short-duration rice varieties as the grain filling had to be completed in a short time (Manful *et al.*, 1996). Only *Ex-Baika*, *Jasmine 85* and *Marshall* had good TGWs (21.1-22.3 g). The high TGW varieties will, therefore, produce more flour and vice-versa. The bulk densities of the varieties studied did not differ significantly ($p>0.05$). Thus, the varieties will have similar holding capacities and dockage characteristics.

Table 2. Grain size and shape classification and mass properties of some commercial rice types in Ghana

Type	Variety	Length (mm)	Width (mm)	L/W ratio	Size Classification*	Shape Classification†	1000-Grain Weight (g)	Bulk density (g/mL)
Local	*Ex-Baika*	6.70±0.01^{b}	2.25±0.01^{c}	3.0±0.0^{b}	Long	Medium	21.3±0.04^{c}	0.91±0.00
	Ex-Hohoe	6.51±0.01^{a}	2.22±0.01^{b}	2.9±0.01^{a}	Medium	Medium	19.5±0.05^{b}	0.89±0.02
	Jasmine 85	6.83±0.01^{c}	2.21±0.01^{b}	3.1±0.02^{c}	Long	Slender	22.1±0.02^{d}	0.87±0.00
	Marshall	6.74±0.01^{b}	2.26±0.01^{c}	3.0±0.0^{b}	Long	Medium	22.3±0.03^{d}	0.87±0.00
Imported (Controls)	*Royal Feast*	6.87±0.01^{d}	1.96±0.01^{a}	3.5±0.0^{d}	Long	Slender	18.6±0.02^{a}	0.89±0.02
	Sultana	6.87±0.01^{d}	1.96±0.01^{a}	3.5±0.0^{d}	Long	Slender	18.4±0.03^{a}	0.87±0.00

^{a,b,c,d}: Rice types with same superscripts in a column are not significantly different at $p \leq 0.05$; *: >7.0: extra long; 6.0-6.99: long; 5.0-5.99: medium; <5.0: short; †: >3.0: slender; 2.1-3.0: medium; 1.1-2.0: bold; <2.0 round

Table 3. Mean chromameter indices of some commercial rice types in Ghana

Type	Variety	L*	a*	b*
Local	*Ex-Baika*	73.98±0.03^{c}	1.46±0.04^{c}	8.36±0.15^{a}
	Ex-Hohoe	69.04±0.19^{a}	6.43±0.05^{e}	10.54±0.06^{c}
	Jasmine 85	72.50±0.38^{b}	1.91±0.10^{d}	9.00±0.06^{b}
	Marshall	74.22±0.42^{c}	1.16±0.10^{b}	9.08±0.10^{b}
Imported (Controls)	*Royal Feast*	78.51±0.51^{d}	0.52±0.03^{a}	11.16±0.26^{d}
	Sultana	78.33±0.21^{d}	0.64±0.06^{a}	10.68±0.19^{c}

^{a,b,c,d}: Varieties with same superscripts in a column are not significantly different at $p \leq 0.05$; L* = Lightness of kernel; a* = Redness of kernel; b* = Yellowness of kernel

Table 4. Mean physical quality characteristics of some commercial rice types in Ghana

Type	Variety	Brokens (%)	Immature grains (%)	Mouldy grains (%)	Discoloured grains (%)	Red rice (%)	Stones (%)	Unshelled paddy (%)	Chalkiness (%)
Local	*Ex-Baika*	32.60^{c}	0.05	2.23^{b,c}	0.14	0.14^{a}	np	np	0.34
	**Ex-Hohoe*	32.70^{c}	np	0.28^{a}	0.31	*	np	np	0.29
	Jasmine 85	13.60^{b}	0.16	1.50^{a,b}	0.58	0.90^{b}	np	np	0.17
	Marshall	18.63^{b}	0.33	0.89^{a,b}	0.90	0.13^{a}	np	np	0.44
Imported (Controls)	*Royal Feast*	0.60^{a}	np	0.28^{a}	0.31	np	np	np	0.02
	Sultana	2.16^{a}	np	0.22^{a}	0.13	0.02^{a}	np	np	0.03

np = not present; *: *Ex-Hohoe* is a variety with predominantly red pericarp colour; ^{a,b,c}: Varieties with same superscripts in a column are not significantly different at $p \leq 0.05$

Table 5: Mean chemical composition of some commercial rice types in Ghana

			Alkali Spreading†		Gel Consistency††			Minerals (mg/kg)		
Type	Sample	Protein (%)	Score	GT*	Value (mm)	Gel strength	Amylose (%)	Iron	Phosphorous	Calcium
Local	*Ex-Baika*	5.80±0.16^{b}	1.00	High	98	Soft	17.5±0.91^{b}	5.3±0.14^{b}	1183.5±2.12^{c}	111.0±1.41^{b}
	Ex-Hohoe	5.60±0.14^{a,b}	1.00	High	75	Soft	22.7±0.06^{d}	6.1±0.14^{c}	1373.7±1.84^{e}	108.0±0.42^{a}
	Jasmine 85	5.81±0.10^{b}	1.42	High	66	Soft	20.2±0.02^{c}	5.0±0.0^{b}	1244.0±4.24^{d}	109.6±0.28^{a,b}
	Marshall	5.93±0.01^{b}	1.25	High	66	Soft	19.3±0.01^{c}	8.0±0.28^{d}	1166.9±1.13^{b}	109.6±0.14^{a,b}
Imported (Controls)	*Royal Feast*	5.30±0.15^{a}	2.00	High	97	Soft	16.0±0.43^{a,b}	2.1±0.0^{a}	658.4±0.57^{a}	108.2±0.28^{a}
	Sultana	5.62±0.14^{a,b}	2.17	High	69	Soft	15.9±0.10^{a}	2.7±0.07^{a}	686.0±2.69^{a}	108.3±0.42^{a}

^{a,b,c,d,e}: Varieties with same superscripts in a column are not significantly different at $p \leq 0.05$; †: Alkali spreading scores correspond to gelatinization temperature as follows: 1-2, high (74.5-80ºC); 3, high-intermediate; 4-5, intermediate (70-74ºC); and 6-7, low (<70ºC); ††: The gel consistency values are classified as: soft (61-100 mm), medium (41-60 mm) or hard (26-40 mm); *: Gelatinization temperature

Size and shape are among the grain characteristics that dictate the marketability and commercial viability of rice (Khush *et al*., 1979). Therefore, local varieties can be marketed based on the size and shape preference of consumers.

The local varieties had significantly lower ($p<0.05$) whiteness values and were less yellowish (low b* values), but more reddish (high a*values) than their imported counterparts (Table 3). The low whiteness index (L*) observed for *Ex-Hohoe* was expected because of its naturally red pericarp. Grain colour has implications for consumer preference because of the high visual appeal of white milled rice; which is also associated with grain superiority in Ghana (Adu-Kwarteng *et al.*, 2003) and high market value (Wadsworth, 1994). The imported varieties are, therefore, more likely to attract a higher market value than the locally grown ones.

Physical examination showed more brokens in the local varieties (Table 4). The tolerance levels are for red rice, 4%, for chalky grains, 6%, and for immature grains 2% (Codex Alimentarius Commission, 1990). All the varieties examined were below the tolerance levels and, therefore, meet these quality criteria for market competitiveness.

Cooking and pasting characteristics of rice types: The local varieties had higher iron (5.0-8.0 mg/kg) and phosphorous (1166.9-1373.7 mg/kg) levels, but were similar to their imported counterparts in their protein and calcium levels (Table 5).

Table 6: Pasting characteristics of some commercial rice types as measured using rapid visco-analyzer

Type	Sample	Pasting temp (ºC)	Peak viscosity (cP)	Peak time (min)	Trough viscosity (cP)	Final viscosity (cP)	Breakdown (cP)	Setback (cP)	Retrogradation (cP)
Local	*Ex-Baika*	87.0	3130^{c}	$5.8^{a,b,c}$	1968^{d}	3983	1162^{b}	854	$2016^{a,b,c}$
	Ex-Hohoe	83.8	$2756^{a,b}$	5.7^{a}	1555^{a}	3686	1201^{b}	930	$2131^{b,c}$
	Jasmine 85	86.2	$2731^{a,b}$	$5.8^{a,b,c}$	1732^{b}	3914	$999^{a,b}$	1184	2183^{c}
	Marshall	87.4	$2919^{b,c}$	$5.7^{a,b}$	$1773^{b,c}$	3633	1146^{b}	714	$1861^{a,b}$
Imported (Controls)	*Royal Feast*	88.2	2521^{a}	6.0^{c}	$1874^{c,d}$	3673	647^{a}	1152	1799^{a}
	Sultana	88.2	$2631^{a,b}$	$5.9^{b,c}$	1967^{d}	3742	663^{a}	1112	1775^{a}

^{a,b,c,d}: Varieties with same superscripts in a column are not significantly different at $p \leq 0.05$

The protein contents of the rice varieties (5.30-5.93%) agreed with earlier findings by other researchers who found a range of 5.10-5.30% (Adu-Kwarteng *et al.*, 2003). The percentage loss of ash increased with the increased removal of bran (Singh *et al*., 2000). High levels of potassium, calcium, and phosphorous have also been found in rice bran in Ghana (Amissah *et al.*, 2003). Although some minerals may have been lost through milling, the local varieties still had high mineral content. The significant difference in the mineral contents of the rice varieties makes the local ones nutritionally better than the imported ones. Soft gels and high gelatinization temperatures, with intermediate to high amylose contents (Table 5), characterized the samples. There were significant differences (p<0.05) in the gel consistencies, alkali spreading scores and amylose contents of the samples. Gel consistencies ranged from 66 mm (*Jasmine 85* and *Marshall*) to 98 mm (*Ex-Baika*). This puts all the rice varieties into the soft gel category and gives them the tendency to be soft on cooling (Cagampang *et al.*, 1973). These varieties will have useful application in rice dishes that require grains to cook tender; ranging from plain-cooked rice to dishes that require mashing of boiled rice. The alkali spreading scores (1.00-2.17) placed the samples in the high gelatinization temperature category according to Bhattacharya and Sowbhagya (1972). The high pasting temperatures (83.8-88.2ºC) obtained in this study (Table 6) are consistent with other findings and indicate that the samples will have long cooking times (Suwansri and Meullenet, 2004). The samples are, therefore, non-waxy varieties with crystalline starch structure; a fact corroborated by their low to intermediate amylose contents (15.9-22.7%) as classified by Juliano *et al.* (1981).

Pasting properties have been reported to be affected by amylose (Tester and Morrison, 1990). Amylose content was found to be significantly correlated with peak viscosity, final viscosity and setback in a study by Singh *et al.* (2006). The peak viscosities varied significantly from 2521 to 3130 cP between 5.7-6.0 min of heating. The imported varieties had relatively lower peak viscosities than the local varieties. This implies that the starch granules of the local varieties swelled much more than the imported ones, and hence led to a thicker paste for the local ones. Flour from the local ones will be very useful in foods that need thickening. Preparation of porridge from the local ones will also require comparatively more water and energy input than the imported ones.

Final viscosities varied from 3633 to 3983 cP (Table 6). A large increase in viscosity during the cooling stage shows quick retrogradation (Lii *et al.*, 1995). Low amylose varieties (*Royal Feast* and *Sultana*) had comparatively low retrogradation values compared to the local varieties. This agrees with the findings in some earlier studies (Noosuk *et al.*, 2003). Paste setback values (a measure of the paste hardening on cooling) ranged from 714 to 1184 cP. This is influenced by the amount of amylose leached from granules and remnants of gelatinized starch (Loh, 1992).

The trough (hot paste) viscosity varied significantly from 1555 cP for to 1968 cP. *Ex-Hohoe* was very different from the other varieties in having a significantly lower hot paste viscosity. This means that it is more susceptible to fragmentation of its starch granules and subsequent exudation of amylose during cooking than the other varieties. This is probably due to it being an *Oryza glaberrima* variety. The imported varieties show relatively higher resistance to fragmentation of their starches during cooking.

Starch breakdown differed significantly (p<0.05) among varieties; ranging from 647 to 1201 cP and lower in the imported brands. Breakdown viscosity measures the tendency of swollen starch granules to rupture when held at high temperatures and continuous shearing, and is indicative of the stability of the starch on heating (Patindol *et al.*, 2005). The low breakdown viscosity of a long grain rice results in a cooked rice that is less sticky than its short-grain counterparts (Park *et al*., 2007). High breakdown values point to a rice variety that will produce a sticky cooked product. The two imported varieties will therefore cook firmer than all the local varieties. This means that the imported varieties will be useful in dishes that require rice grains that do not stick together. The local varieties, in contrast, will be very good for dishes that involve mashing the rice into a paste or rolled into dumplings.

Cluster and principal component analysis for physicochemical characteristics of rice types: The rice varieties selected for the study were statistically analyzed for similarities in their physicochemical characteristics

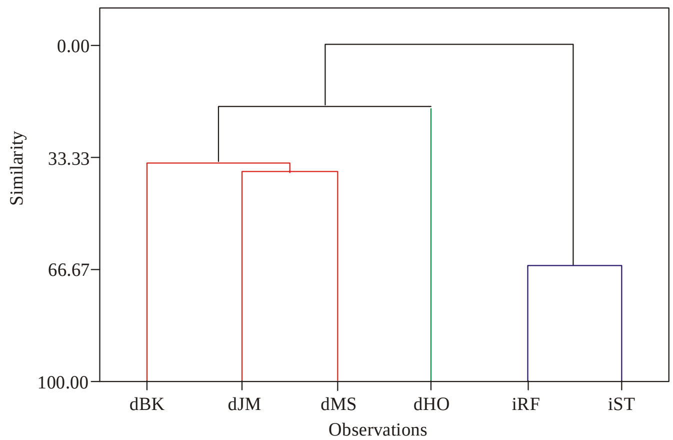

Fig. 1: Cluster observation dendogram for the physicochemical characteristics of some commercial rice types in Ghana
Local: dBK = *Ex-Baika*; dJM = *Jasmine 85*; dMS = *Marshall*; dHO = *Ex-Hohoe* Imported: iRF = *Royal Feast*; iST = *Sultana*

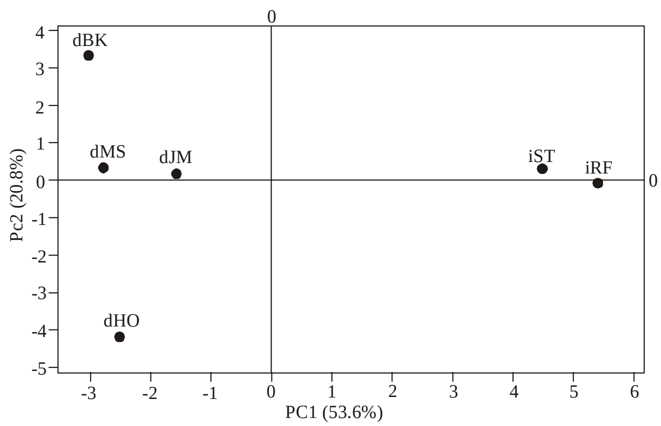

Fig. 2: Sample scores plot for the principal component analysis (PC1 and PC2) of the physicochemical characteristics of some commercial rice types in Ghana
Local: dBK = *Ex-Baika*; dHO = *Ex-Hohoe*; dJM = *Jasmine 85*; dMS = *Marshall*; Imported: iRF = *Royal Feast*; iST = *Sultana*

using cluster observations analysis. Principal Component Analysis (PCA) was further used to establish the patterns and interrelationships existing between the samples and their physicochemical characteristics.

Samples were partitioned into three clusters based on similarities in characteristics (Fig. 1). Three local varieties (*Ex-Baika*, *Marshall*, and *Jasmine 85*) formed the first cluster. *Ex-Hohoe* was alone in the second cluster, probably because it is an *Oryza glaberrima* variety, and the imported brands (*Sultana* and *Royal Feast*) constituted the third cluster. This indicates that similarity between varieties could be divided along imported and locally produced lines. However, among the local varieties, three varieties were very similar in their physicochemical characteristics, leaving out *Ex-Hohoe* in a different cluster. The two imported brands (*Sultana* and *Royal Feast*) are also similar in their physicochemical characteristics.

Principal component analysis applied to the physicochemical characteristics of the rice varieties shows that two components explained a total of 74.4% of the total variability in the data. Principal Component 1 (PC1) accounted for 53.6% of the total variation in the physicochemical characteristics; principal component 2 (PC2) accounted for 20.8% on the sample score plot (Fig. 2). The loadings of the samples on the score plot buttresses the clusters observed in the dendogram (Fig. 1). The imported brands were similar and loaded on the positive side of PC1, whereas the local varieties were on the negative side of PC1. However, *Ex-Hohoe* was loaded negatively on PC2, whereas the remaining local varieties were loaded positively to show differences among local varieties (Fig. 2).

The sample score plot corresponds to the variable weights plot (Fig. 3). Grain length, L/W ratio, lightness and yellowness of colour, setback, trough viscosity, peak

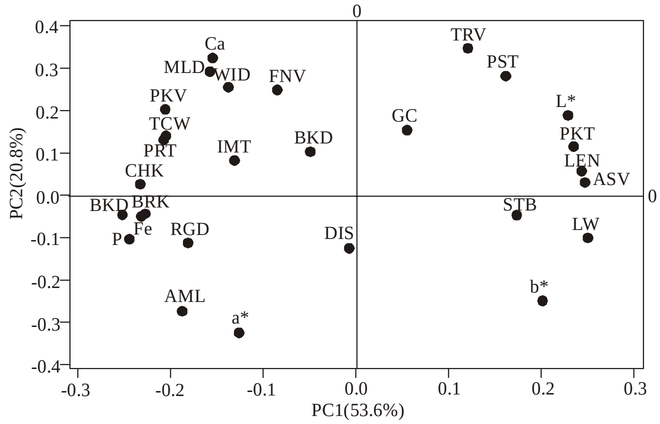

Fig. 3: Variable weights plot for principal component analysis (PC1 and PC2) of the physicochemical characteristics of some commercial rice types in Ghana
a* = redness of rice grains; AML = amylase; ASV = alkali spreading value; b* = yellowness of rice grains; BKD = bulk density; BRK = broken grains; Ca = calcium; CHK = chalkiness; DIS = discoloured grains; FNV = final viscosity; GC = gel consistency; IMT = immature grains; L* = lightness of grains; LEN = length of grains; LW = length/width ratio; MLD = mouldy grains; P = phosphorous; PRT = protein; PST = pasting time; PKV = peak viscosity; PKT = peak time; RGD = retrogradation; TGW = 1000-grain weight; TRV = trough viscosity; WID = width

time, pasting time, alkali spreading value, and gel consistency are positively loaded on PC1. This indicates that the imported brands are related by these characteristics. All variables from the physical examination of the samples, grain weights and densities, width and redness of samples, minerals and other chemical characteristics loaded negatively on PC1. This corresponds to the local samples on the sample score plot. The local varieties are, therefore, related in their chalkiness, moldiness, immature grains, broken grains, grain width, and 1000-grain weight. Most of these are parameters that indicate poor post harvest handling of rice. The position of *Ex-Hohoe* on the sample score plot corresponds to the place of redness (a*) and amylose (AML) on the variable weight plot. The difference observed between *Ex-Hohoe* and the other local varieties is, therefore, due to its naturally reddish pericarp color and high amylose content.

CONCLUSION

From the results of the physicochemical characteristics, the imported rice brands were found to be different from the domestic varieties based on their grain dimensions and whiteness and yellowness of kernels. The locally grown varieties had higher values for their grain width, weight, and densities. They also had higher values for other parameters determined from physical examinations that negatively affect physical quality (i.e., brokens, moldiness, chalkiness, and immature grains). They, however, had a high mineral content.

Differences based on physicochemical characteristics also existed among locally cultivated rice varieties, with *Ex-Hohoe*, an *Oryza glaberrima*, being different from the other three local varieties due to its naturally reddish pericarp color and high amylose content. Although the imported brands will be useful in foods that do not require grains to stick together, the local varieties will be good for those foods that require mashing the rice into a paste or rolled into dumplings. Future breeding programs can target improvement in grain colour and appearance while emphasizing better post harvest handling of rice.

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