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Rheological and sensory properties of rice varieties from Improvement Programmes in Ghana

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Abstract: The physical, rheological and sensory properties of six rice (*Oryza sativa*) varieties, from two improvement programmes in Ghana, were evaluated with the aim of establishing their specific food uses. The varieties were *Ex-Baika, Bouake, Ex-USA, Local perfumed, Rustic and Tox 3233-31-6-2.* Sensory evaluation and consumer acceptability of both the raw and cooked form of varieties were conducted using trained panellists with a *US No. 5* market sample as control. The mean total milling recovery (TMR) ranged from 36.0 to 64.6%. *Ex-USA* and *Local perfumed* recorded the highest levels of brokens while the other varieties had minimal incidence of chalkiness and were slender in shape. Apart from grain size, slenderness and overall acceptability, there were significant differences ($p < 0.05$) among the mean scores of all the other attributes evaluated for raw rice. *Rustic*, despite its appreciable levels of both black and white specks, was the most preferred followed by *Ex-Baika, Tox3233-31-6-2, Bouake, Ex-USA, Local perfumed* and *US No.5.* All the samples with the exception of *Tox 3233-31-6-2* had their viscosities increasing more than two fold at the end of the cooling period. The order of increasing tendency to gel upon cooling was *US No. 5< Ex Baika< Tox 3233-31-6-2< Local perfumed < Bouake< Rustic < Ex USA*. There were significant differences ($p<0.05$) in all the attributes of the cooked rice but overall, *Ex-Baika, Bouake and Ex-USA* came close to *US No. 5* control sample.

Keywords: Rice; varieties; physical, rheological and sensory properties

Introduction

Rice (*Oryza sativa L.*) is an important convenience food for urban consumers in Ghana and much of sub-Saharan Africa (Tomlins *et al.,* 2007). Among cereals in Ghana, the per capita consumption of rice is second to maize (Quaye *et al.*, 2000). Consumption of rice in Ghana has increased tremendously over the last few years and this is mainly as a result of increased urbanization and the relative ease with which it can be cooked. However, the increasing demand for rice (both in quantity and quality) far outweighs local production. Over the past few years rice production in Ghana has stagnated around 170,000 metric tons of milled rice with a self sufficiency ratio of 22% (MoFA, 2005). In addition to this, the quality of the rice produced is variable. To make up for the shortfall, greater part of rice consumed in Ghana is imported. In the year 2005, figures from the Ministry of Trade and Industry showed that about 600,000 metric tons of rice was imported. This represented a value of roughly $200 million, contributing 6% of Ghana's trade balance deficit.

The need to increase production and improve the quality of locally produced rice to make it more competitive with imported rice cannot be over emphasized. Several factors have been found to account for this variable quality; the most obvious ones being rather poor physical and sensory properties. It is common to find locally produced rice containing a lot of foreign matter (inorganic and organic) such as stones and weed seeds, other varieties with high levels of chalky grains, brokens and damaged grains. It is widely believed that these quality defects are as a result of the use of poor planting materials and agronomic practices, late harvesting and inappropriate post-production handling practices. It is therefore possible through the use of appropriate agronomic and post-production handling practices to improve the quality of locally produced rice.

In recent times, the Agricultural Research Institutions in Ghana have been engaged in a number of rice improvement programmes to enhance both yield and quality. Manful *et al*. (1996) noted that although considerable work has been done on the yield and agronomic properties of rice in Ghana, not much has been done on the sensory and pasting properties of the crop. This situation has since not changed. Adu-Kwarteng *et al.* (2003) found out that some promising lines of the new varieties had good grain size and shape, good endosperm appearance, milling quality and higher amylose content. However, that work did not assess the starch and sensory characteristics of the varieties. Ghanaians use rice in

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several food preparations such as in the form of boiled rice, mashed as porridge, especially for weaning children or cooked rice which is mashed and rolled into round balls eaten with soup as well as flour in the several pastry preparations. It is therefore important that the specific food uses of these new rice varieties are well established. This paper therefore concerns an evaluation of the physical, pasting and sensory properties of six newly introduced rice varieties in Ghana.

Materials and Methods

Materials and sample preparation

Six rice varieties namely *Ex-Baika, Bouake, Ex-USA, Local perfumed, Rustic and Tox 3233-31-6-2* produced by the Savannah Agriculture Research Institute of the Council for Scientific and Industrial Research (CSIR) of Ghana and the University of Ghana Agriculture Research Station (UGARS) were used for the study. 500 g of paddy of each variety (moisture content ≤ 12%) were dehusked with a rice dehuller (type THU 35B, Satake Co. Ltd. Tokyo, Japan), and the brown rice recovered polished in a BS08A single pass rice pearler with the degree of whiteness set at "medium".

Physical properties

Physical properties studied were the grain size and shape, one thousand grain weight, total milling recovery, brokens, chalkiness (endosperm appearance) and grain colour. Grain size and shape were measured on five replicates of ten kernels per sample using a micrometer screw gauge (Mitoyo Co.) and data interpreted using WARDA (1995) and ISO classification. The Thousand Grain Weight (Dorsey-Redding *et al.,* 1991) was carried on three replicates of 1000 randomly selected milled whole kernels. These were counted and weighed to determine the thousand grain weight. Total milling recovery was determined by dividing the weight of milled rice recovered by the weight of the paddy sample milled (Adu-Kwarteng *et al*., 2003). The percentage broken, chalky rice as well as the *L, a, b* colour parameters (Minolta CR310, Minolta Co. Ltd., Japan) of the grain were determined from five replicates of 100g samples, according to methods outlined by WARDA (1995).

Rheological properties

The rheological properties of 8% rice flour slurries (~40 g, corrected to 14% moisture, in 420 ml deionized water) were measured with a Brabender Viskograph-E (Brabender® OHG, Duisburg, Germany). The slurry was heated from 50 to 95ºC at a rate of 1.5ºC /min, held at 95ºC for 15 min, and cooled to 50ºC at 1.5ºC /min and finally held at 50ºC for 15min. The following parameters were determined from the Brabender Viscograph pasting curve:

- peak viscosity (maximum viscosity during heating),
- hot paste viscosity (trough),
- cold paste or final viscosity (viscosity at end of cooling period)
- the breakdown was calculated as the difference between peak and trough viscosities.
- the setback was calculated as the difference between the cold paste or final viscosity and the peak viscosity.

Sensory evaluation

Sensory evaluations were carried on raw rice and cooked rice samples. Parameters of the raw rice and cooked samples were scored by a trained panel of ten using a modified version of quantitative descriptive analysis (QDA) as explained by Tomlins *et al.* (2005).

Raw milled rice

Table 1 gives the fifteen sensory attributes developed by the panellists for uncooked milled rice. Intensity for the sensory attributes was scored on a 100 mm unstructured scale, anchored with the terms '*not very'* at the low end and '*very*' at the high end.

Cooked milled rice

Approximately 300 g of rice was cooked in 450 ml of salted water. Three rice samples of about 50 g each served at ambient temperature (25- 30°C) and coded with 3-figure random numbers were served in random order to each panellist. Sensory parameters assessed colour, odour, taste and texture using 12 developed descriptive terms (Table 2).

The intensities of each parameter were scored on a 100 mm unstructured scale, anchored with the terms *'not very'* at the lower end and *'very'* at the high end. Panelists rinsed their mouth with mineral water before tasting each sample.

Statistical data analysis

The data obtained were analyzed using analysis of variance (ANOVA) (Microsoft Excel. 2007) at a 95% confidence level. The individual sensory attribute data were analyzed by one-way ANOVA to determine significant variation among the mean sensory scores.

Table 2. Sensory attributes developed by panel for cooked rice

Sensory Attribute	Description of Attribute
Uniform appearance	rice grains that were uniform in appearance and colour
Black specks	rice grains with blackened ends
Whitish appearance	pale/pallid appearance
Yellow colour	Yellow colour of rice grains
Brown colour	Brown colour of rice grains
Creamy flavour	creamy taste from freshly cooked rice
Typical rice odour	odour characteristic of freshly cooked rice
Sweet taste	Typical delightful taste of rice
Sour taste	Unappealing/unpleasant taste
Sticky texture	rice grains that have a gluey property
Grainy texture	gritty/coarse mouthfeel
Hard texture	inflexible mouthfeel

Table 1. Sensory attributes developed by panel

Sensory Attribute	Description of Attribute
Uniform colour	rice grains that were uniform in appearance and colour
Black heads	grains with blackened ends
White bellies	grains with a white and opaque portion in the ventral part
Yellowness	yellow colour of rice grains
Brown colour	brown colour of rice grains
Cream colour	rice grains having the colour of fresh cream
Brightness	opposite to dull in appearance
Translucency	rice grains that are semi-transparent (this may be demonstrated by holding them up to the light)
Clean appearance	free of foreign matter or discoloration
Unshelled paddy	completely unhusked grains
Whole grains	grains that are completely intact as opposed to broken grains
Long shape	grains that are significantly longer than they are wide
Oval shape	grains that are oval in shape as opposed to long, slender or broken
Size	refers to the size of the grain irrespective of shape
Slenderness	grains that are significantly thinner than normal

Table 3. Physical qualities of six newly introduced rice varieties in Ghana[d]

Variety	Broken Fraction (%)	Chalky Grains (%)	TMR (%)	Length/ Width of Grain	TGW (g)	Colour (ΔE)
Ex-USA	55.18 (0.36)	0.80 (0.08)	61.03 (0.35)	4.18 (0.16)	20.61 (0.30)	9.34 (0.23)
Local perfumed	51.10 (0.39)	0.27 (0.05)	56.84 (0.30)	4.59 (0.40)	16.43 (0.21)	5.11 (0.17)
Bouake	30.58 (0.36)	0.37 (0.05)	64.62 (0.60)	4.29 (0.18)	20.28 (0.38)	9.34 (0.24)
Ex-Baika	16.02 (0.12)	0.19 (0.03)	63.33 (0.43)	4.24 (0.23)	18.46 (0.41)	7.28 (0.17)
Tox 3233-31-6-2-3-1	26.96 (0.15)	0.08 (0.08)	36.38 (0.44)	3.85 (0.20)	22.55 (0.27)	4.52 (0.03)
Rustic	30.14 (0.26)	0.68 (0.03)	63.55 (0.41)	3.48 (0.60)	18.69 (0.27)	3.48 (0.02)
US No 5 (Control)	11.16 (.028)	0.00 (0.03)	*	4.09 (0.22)	18.23 (0.21)	-
Mean	31.82	0.34	57.63	4.10	19.06	-
S.E	6.21	0.11	4.40	0.13	0.59	-

* Control sample was already milled; TMR= Total Milling Recovery; ΔE= Change in Colour based on the equation ΔE = [(ΔL)2 + (Δa)2 + (Δb)2]1/2
TGW = Thousand Grain Weight
d Values are means with standard deviations in parenthesis

Table 4. Rheological Properties (in BU) of six newly introduced rice varieties in Ghana[a]

	Pasting temp	Peak viscosity	Hot paste viscosity	Cold paste viscosity	Breakdown	Setback
Ex USA	84.9 (1.0)	79.0 (13.0)	70.5 (9.5)	195.0 (24.0)	8.5 (3.5)	115.0 (11.1)
Bouake	86.2 (0.1)	87.0 (3.0)	83.0 (1.0)	211.0 (0.0)	4.5 (1.50)	124.0 (4.2)
Local perfumed	86.8 (0.4)	120.0 (3.0)	120.0 (3.0)	283.0 (9.0)	0.0 (0.0)	163.0 (6.0)
Ex Baika	83.7 (0.1)	203.0 (2.0)	181.0 (1.0)	381.0 (3.0)	21.5 (0.5)	177.0 (2.0)
Tox 3233-31-6-2-3-1	86.3 (0.1)	227.0 (0.0)	224.5 (1.5)	387.0 (3.0)	2.5 (1.5)	159.7 (3.1)
US No.5 (Control)	81.2(0.1)	248.5 (3.5)	162.0 (3.0)	440.0 (4.0)	86.0 (1.0)	190.7 (1.5)
Rustic	86.9 (0.1)	86.0 (0.1)	83.0 (0.1)	211.0 (0.1)	3.0 (0.1)	128.0 (1.1)

[a]Values are averages of triplicates in BU with standard deviation in parenthesis.

Results and Discussion

Physical properties

Table 3 indicates that, except for *TOX 3233-31-6-2-3-1* and *Local Perfumed* varieties, all the other rice varieties gave appreciably good total milling recovery values as explained by Adu-Kwarteng *et al.* (2003). The relatively high percentage of broken fractions could be attributable to low moisture content (Internet: International Rice Research Institute, 2008) and chalkiness due to the high correlation between broken fraction and percentage of chalkiness (Table 3). Chalkiness indirectly contributes to rice breakage through easier craking (Bhattacharya, 1980). Percentage chalkiness higher than 1% is considered not acceptable (Bhashyam, 1983). Although chalkiness cannot be seen after cooking, it is an important physical property as it can determine whether a particular rice sample attracts a competitive price on the market (Khush *et al.*, 1979; Indudhara and Bhattacharya, 1982). All the rice varieties had acceptable percentages of chalkiness with *Ex USA* and *Rustic* having the highest percent chalkiness of 0.80% and 0.68% respectively. The acceptable range for the thousand grain weight (TGW) is 20 to 30g. Values below 20g indicate presence of immature,

Table 5. Mean sensory values of uncooked samples of six newly introduced rice varieties in Ghana[b]

Attributes	*Ex Baika*		*Local Perfumed*		*Bouake*		*Rustic*		*Ex USA*		*Tox*		*US No. 5 (Control)*	
Uniform colour	84.9	(2.77)	73.6	(2.18)	85.2	(3.92)	77.5	(3.52)	78.1	(3.73)	75.3	(3.06)	85.3	(3.10)
Black heads	1.4	(0.31)	2.2	(0.29)	1.8	(0.33)	2.3	(0.37)	2.2	(0.33)	7.2	(0.49)	3.9	(0.38)
White bellies	3.0	(0.30)	12.2	(0.53)	11.4	(0.54)	12.8	(0.44)	14.5	(0.34)	13.3	(0.47)	7.8	(0.36)
Yellowness	3.6	(0.43)	3.9	(0.50)	15.1	(0.67)	17.4	(0.50)	7.3	(0.40)	2.6	(0.31)	17.7	(0.50)
Brown colour	1.4	(0.22)	9.6	(0.48)	4.4	(0.56)	4.2	(0.49)	7.9	(0.41)	4.2	(0.59)	3.2	(0.33)
Brightness	79.5	(2.75)	56.5	(1.69)	57.9	(1.84)	69.5	(3.98)	69.5	(3.50)	67.7	(2.270	78.4	(3.00)
Translucency	61.8	(1.90)	28.0	(1.00)	63.2	(3.18)	62.0	(2.09)	62.0	(1.19)	20.7	(1.02)	68.0	(2.17)
Clean appearance	80.5	(2.62)	61.9	(2.45)	71.0	(2.47)	71.9	(3.03)	71.9	(1.46)	62.1	(2.43)	87.8	(2.18)
Creamy colour	64.5	(2.56)	58.3	(1.87)	66.2	(6.42)	60.8	(1.61)	60.8	(1.38)	58.0	(1.56)	66.2	(2.28)
Chalky appearance	14.1	(0.55)	22.4	(0.75)	12.1	(0.59)	9.0	(0.52)	9.0	(0.87)	39.1	(1.350	14.4	(0.50)
Unshelled paddy	1.5	(0.27)	3.5	(0.43)	1.8	(0.25)	1.9	(0.23)	1.9	(0.30)	1.8	(0.25)	1.1	(0.10)
Whole grains	72.7	(2.32)	71.3	(2.05)	84.5	(3.40)	70.4	(3.66)	70.4	(1.74)	63.8	(2.18)	86.0	(3.55)
Long shape	75.7	(6.58)	71.7	(7.61)	65.5	(8.79)	74.4	(6.00)	74.4	(7.28)	56.5	(9.70)	78.9	(5.82)
Size	63.6	(2.37)	40.6	(9.02)	59.3	(9.33)	50.6	(9.10)	50.6	(7.75)	45.9	(7.58)	52.2	(10.47)
Slenderness	36.8	(8.20)	18.8	(6.12)	46.3	(11.08)	26.7	(6.99)	26.7	(6.97)	42.6	(9.96)	26.7	(7.74)
Overall acceptability	67.8	(8.16)	52.7	(6.66)	59.8	(8.69)	68.1	(3.92)	68.1	(7.13)	37.9	(6.98)	61.1	(10.60)

[b] Values are mean percentage sensory scores with standard errors in parenthesis

damaged or unfilled grains (Adu-Kwarteng *et al.*, 2003). The TGW values of the test samples were rather on the low side with *Tox 3233-31-6-2* having the highest TGW of 22.55 g. *Local perfumed, Ex-Baika, Rustic* and *US No.5* had TGW of less than 20.00g. The length to width (L/W) ratios mean all the varieties were slender in size according to the (WARDA, 1995) classification. The order of increasing difference in colour from the control, *US No. 5*, was found to be *Ex-USA < Bouake< Ex-Baika < Local Perfumed< Tox 3233-31-6-2 and Rustic.* In Ghana, most consumers are of the view that white rice is superior (Adu- Kwarteng *et al.,* 2003).

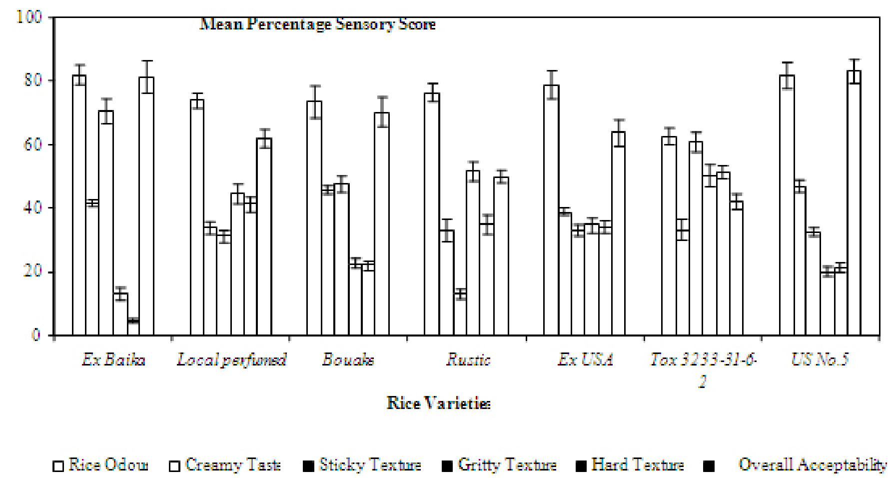
Rheological Properties

Table 4 shows that rice varieties *Ex-USA*, *Bouake* and *Rustic* have significantly lower peak paste viscosities than the rest. Most probably, this may be due to *Ex-USA*, *Bouake* and *Rustic* having high starch concentration and less amylopectin. With native starches, the greater the amount of amylopectin the more viscous the starch paste, (Internet: Food Resource, 2008; Thomas and Atwell, 1999). Paste peak viscosity measures the extent by which starch granules swell in the presence of water, heat and sometimes shear. Starch swelling is mainly due to the activity of the amylopectin, but this can be restricted by amylose and protein (Shin *et al.*, 1985; Fan and Marks, 1999; Inouchi *et al.,* 2000). The viscosities of the samples at 95˚C were comparable and as expected slightly lower than their respective peak viscosities. The hot paste viscosity of *Local Perfumed* did not change from the peak viscosity but that of *Tox 3233-31-6-2, Bouake* and *Rustic* reduced rather marginally and those of *Ex-USA* and *Ex-Baika* reduced markedly. However at the end of the cooling period, the cold paste viscosities of all the samples showed doubling of their viscosities, the only exception being the *Tox 3233-31-6-2 variety*. Viscosities at the start of the holding period and during cooling reflect the ease of cooking starch and paste stability, respectively (Zobel, 1984). Zobel (1984) further explained that increase in paste viscosity when a hot paste is cooled is governed by the tendency of the starch to undergo retrogradation. Breakdown viscosity measures the tendency of swollen starch granules to rupture when held at high temperatures and continuous shearing (Patindol *et al*., 2005). The least breakdown viscosity of the starch granules of *Local Perfumed* rice variety therefore makes it useful for dishes involving boiled rice for grains that do not stick together. Rice variety *Ex-Baika* may be useful in preparing the type of popular Ghanaian dish in which boiled rice is mashed and constituted into paste-like food balls and eaten with soup.

Sensory Properties

Table 5 shows the mean sensory scores of the uncooked rice samples. There were no significant differences (p>0.05) in the mean scores of three attributes namely grain size, slenderness and overall acceptability between the control and the other samples. But there were significant differences ($p < 0.05$) between the mean scores of all the other attributes evaluated. Panellists adjudged *Local perfumed* as having the smallest and *Ex-Baika* largest grain size. These findings did not agree with the thousand grain weight measurements obtained

Figure 1. Sensory scores of odour, taste, textural attributes and overall acceptability of six newly introduced rice varieties in Ghana



in Table 3. This may be due differences in densities of grains. *Rustic,* though had appreciable levels of both black and white specks, was the most preferred followed by *Ex-Baika, Tox 3233-31-6-2,Bouake, Ex-USA, Local perfumed* and *US No.5.*

Analyses of the data on the sensory evaluation of the cooked rice varieties showed some significant differences ($p<0.05$) in a number of the sensory parameters of the cooked samples. The key ones are shown in Figure 1. Panellists adjudged *Tox 3233-31-6-2* variety to be the odd one out in terms of the expected typical rice odour. In terms of the creamy taste, *Ex-Baika* and *Ex-USA* were found to be comparable to the control variety, *US No.5*. Patindol *et al.* (2005) explained that breakdown viscosity measures the tendency of swollen starch granules to rupture when held at high temperatures and continuous shearing. Oduro-Yeboah *et al.* (2007) also explained that bursting starch granules absorb a lot of water making them into very good paste that set very well with good adhesive (sticky) properties. The highest breakdown viscosity of the starch granules of *Ex-Baika* rice variety therefore makes it sticky and useful for dishes involving boiled rice grains that do stick together such as rice balls eaten with soup. The soft texture of *Bouake, Ex-USA* and *Rustic* may be due to their relatively low setback. The retrogradation tendency of the rice starch is defined by the setback (Traore, 2005). Their soft texture could be also due to low amylose content. Usually low amylose content varieties have soft texture when they are cooked (Webb 1991). *Bouake, Ex-USA* and *Rustic* would be useful for preparing rice porridge for children. Panelists adjudged *Rustic* to be non-sticky.

Conclusion

The varieties studied exhibited good physical characteristics especially milling recoveries, shape and low incidence of chalkiness. Though the level of broken fraction was high, overall acceptability of the varieties was better than the control sample in the raw state. Significant differences ($p<0.05$) were observed in all the attributes of cooked rice but overall, *Ex-Baika, Bouake* and *Ex-USA* were very close to the quality of *US No.5* used as the control. *Local perfumed* and *Rustic* rice varieties recorded low breakdown viscosities so by this starch property they are useful for dishes involving boiled rice for grains that do not stick together. The very sticky nature of *Ex-Baika* (the variety with the highest breakdown viscosity) makes it useful for preparing rice balls; a popular Ghanaian dish in which boiled rice is mashed and constituted into paste-like food balls and eaten with soup. The soft texture of *Bouake, Ex-USA* and Rustic makes them useful for preparing rice porridge for children.

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