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Rice grain quality: A comparison of imported varieties, local varieties with new varieties adopted in Benin

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ABSTRACT

This study was carried out in the grain quality laboratory of the Africa Rice Center in Benin to determine the physicochemical and cooking characteristics of some rice varieties consumed in Benin where is widely cultivated and consumed as a staple. The physicochemical properties of fifteen rice varieties, five imported, five previously cultivated in Benin and five upland varieties, newly developed by the Africa Rice Center were compared. Protein content ranged from 6.4 to 7.7% among the imported and previously cultivated varieties and from 10.6 to 10.8% among the newly developed varieties by the Africa Rice Center. The gel consistencies of the previously cultivated ranged from 6.0 to 71.3 mm with the exception of ADNY 11 which had a gel consistency of 100 mm while the imported and newly developed varieties had gel consistencies ranging from 95 to 100 mm. The cooking times differed among varieties. Two previously cultivated varieties – ADNY 11 and TOX LONG – had cooking times of less than 20 min while a newly developed variety, NERICA 1 had the longest cooking time of 26 min. It is suggested that greater attention be subsequently paid to grain quality characteristics in African rice breeding programs in order to meet consumer preferences on the continent.

1. Introduction

Rice has become an important staple diet in Benin. Rice consumption in the country drastically increased at an annual rate of 47% between 2001 and 2005 compared to the annual average of 6.55% for West Africa (Africa Rice Center, 2007, Chapter 1). For most Beninese, preference is for imported rice over locally produced rice. This has been attributed to several factors including variations in physical characteristics, presence of foreign matter, nutritional quality and cooking behaviors. Rice research in the country up to now was focused on the development of improved varieties with better yield potential and stress tolerance. However, there is a lack of information on the grain physical properties, sensory attributes and processing characteristics of the different rice varieties being cultivated by farmers in the country. The objective of this study was therefore to determine the differences in physical and cooking properties between some newly developed varieties by the Africa Rice Center, some previously cultivated varieties and some imported varieties.

2. Materials and methods

2.1. Materials

Five previously cultivated varieties, namely ADNY 11, BERIS 21, IDSA1, TOX LONG and IR841 and five newly developed varieties by the Africa Rice Center (NERICA1, NERICA3, NERICA4, NERICA6, and NERICA7). All the varieties were harvested at full maturity (35 days after 50% heading). Paddy samples were hand threshed and sun dried until a moisture content of about 14% was attained. All the samples were then stored under ambient conditions (about 27 °C and a relative humidity of 43%) in loosely tied cotton bags, for a period of three months. Milled imported rice varieties were purchased from the local market and used as reference samples. Table 1 shows the list and the sources of the selected varieties.

2.2. Methods

2.2.1. Milling

The dried samples were dehusked in a THU-34A Satake Testing Rice Husker (Satake, Japan). The brown rice obtained was whitened in a BS08A Satake single pass Friction Rice Pearler (Satake, Japan)

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with the degree of whiteness set between 'Low' and 'Medium' on the equipment.

2.2.2. Grain dimensions

For each rice variety (laboratory milled or market sample), 10 whole grains were randomly selected and the length and width determined using a micrometer screw gauge. This measurement was carried out in triplicate.

2.2.3. Amylose content

The cleaned milled grains were ground in an Udy Cyclone Mill (Udy Corp., Fort Collins, USA) with a 1.0 mm mesh screen. Amylose content was determined by Auto-Analyzer (Bran + Luebbe GmbH; Germany) with an Automated Analyzer Control and Evaluation software for Windows Ver. 5.30 (2001) using the method of Juliano (1971).

2.2.4. Determination of protein content

The samples were ground just as for the determination of amylose above.

Total nitrogen content was determined by colorimetric based on Berthelot reaction (Walinga, Van Vark, Houba, & Van der Lee, 1989). Protein content was calculated by multiplying total nitrogen content by 5.95, the constant to convert nitrogen content to protein content in rice-and expressed on a dry matter basis of milled rice.

2.2.5. Grain hardness

Grain hardness was measured using a Kiya grain hardness tester. (Fujihara Seisakusho LDT, Japan). Ten grains were used in the determination of hardness for each rice sample. The handle of the equipment was initially turned anti-clockwise to make room to place a grain on the sample table. Consequently, the handle was turned clockwise until a cracking sound was heard. At this time, the black pointer returns to the zero point and the "mother pointer" (red) remained. The reading of the "mother pointer" (kg) indicated the hardness of the grain. This measurement was carried out in triplicate.

2.2.6. Chalkiness

Two hundred whole grains were selected randomly and visually assessed for chalkiness. A score of 1 (less than 10% chalkiness), 5 (10–20% chalkiness) or 9 (over 20% chalkiness) was given to each sample according to the standard evaluation systems of the International Rice Research Institute (IRRI, 1996).This determination was carried out in triplicate.

2.2.7. Whiteness and translucency

The whiteness and translucency of the milled rice were determined using an MM-1B Satake milling meter (Satake engineering Co. Ltd., Japan). The Satake milling meter was calibrated using the "standard white and brown plates". The sample case was filled with grains and placed in the sample inlet port. The values of whiteness and translucency displayed on the screen were recorded. This measurement was carried out in triplicates.

2.2.8. Cooking properties

2.2.8.1. Cooking time.

Five grams of milled rice of each sample was taken in triplicate and poured into 135 ml of vigorously boiling distilled water in a 400 ml beaker and covered with a watch glass. After 10 min of further boiling, 10 grains were taken out every minute with a perforated ladle. The 10 grains were pressed between two petri dishes and the grains were considered cooked when at least 9 out of the 10 grains no longer had opaque centers. The time was then recorded.

2.2.9. Grain elongation ratio on cooking

The lengths of 10 milled grains were measured with a vernier caliper and put into a wire cylinder. The wire cylinder was placed into vigorously boiling distilled water in a 400-ml beaker. After 1 min, the beaker was covered and the regulator of the hot plate set to "medium". Samples were cooked according to the cooking times determined above. The lengths of the 10 cooked grains were then measured. Elongation ratio was determined in triplicate and calculated as follows: **Elongation ratio = Average length of cooked grains/Average length of raw grains.**

2.2.10. Swelling ratio

Eight grams of milled rice was put into a wire mesh cooking basket. The height of the raw rice in the cooking basket was measured using a vernier caliper (H1). The samples were then cooked according to the cooking times determined above. The cooking basket was subsequently removed and stood erect for 2 min for the water to drain off The height of the cooked rice in the cooking basket was measured using a vernier caliper (H2). This determination was carried out in triplicate and the swelling ratio calculated as follows: Swelling ratio = H2/H1.

2.2.11. Water uptake ratio

Eight grams of milled rice was weighed and put into a wire mesh cooking basket. The initial weight of the cooking basket plus raw rice (W1) was taken. The cooking basket was lowered into 160 ml boiling water in a 400 ml beaker with the regulator of the hot plate switched to "high". After 1 min, the regulator was turned to "low" and the beaker was covered with a watch glass. The sample and the cooking basket were then removed just after the cooking times determined above were reached. The sample and the cooking basket were stood erect for 2 min for the water to drain off. The final weight of the cooked rice and cooking basket (W2) was then measured. This determination was carried out in triplicate. The water uptake ratio was determined as follows: Water uptake ratio = (W2−W1)/8.

2.2.12. Gel consistency

Gel consistency was determined according the method of Cagampang, Perez, and Juliano (1973). This measurement was carried out in triplicate.

Table 1
List of selected rice varieties.

Grouping	Name	Source[a]
Imported rice[a]	ELEPHANT	Thailand
	GINO	Thailand
	SAVANA	Thailand
	SPECIAL RICE	Thailand
	SULTANA	Thailand
Previously cultivated varieties	ADNY 11	Liberia (CARI[a])
	BERIS 21	Benin (INRAB[a])
	IDSA1	Côte d'Ivoire (CNRA[a])
	IR841	Philippines (IRRI[a])
	TOX LONG (TOX 3108-56-4-2-2-2)	Ghana (CRI[a])
Newly developed varieties	NERICA1 (WAB 450-IBP-38-HB)	Côte D'Ivoire (AfricaRice)
	NERICA3 (WAB 450-IBP-28-HB)	Côte d'Ivoire (AfricaRice)
	NERICA4 (WAB 450-IBP-91-HB)	Côte D'Ivoire (AfricaRice)
	NERICA6 (WAB 450-IBP-160-HB)	Côte d'Ivoire (AfricaRice)
	NERICA7(WAB 450-IBP-20-HB)	Côte d'Ivoire (AfricaRice)

CNRA (Ex- IDESSA) = Centre National de Recherche Agricole.
IRRI: International Rice research Institute.
CARI: National Agricultural Research Institute.
CRI: Crop research Institute.
[a] Imported rice verities are known by their brand name no clear information on their scientific names and their sources was available.

Table 2
Shape and size classifications of rice varieties.

Grouping	Varieties	Length (mm)	Width (mm)	L/W	Size classification	Shape classification
Imported rice	ELEPHANT	7.18 (0.32)	1.98 (0.08)	3.63	Long	Slender
	GINO	7.16(0.35)	2.05(0.10)	3.49	Long	Slender
	SAVANA	7.23(0.13)	2.09(0.08)	3.46	Long	Slender
	SPECIAL RICE	7.11 (0.26)	2.04(0.06)	3.49	Long	Slender
	SULTANA	7.20(0.28)	2.07(0.09)	3.49	Long	Slender
	Mean	7.17	2.05	3.51	–	–
Previously cultivated varieties	ADNY11	6.92(0.25)	2.38 (0.12)	2.91	Long	Intermediate
	BERIS 21	6.92(0.28)	2.54(0.20)	2.72	Long	Intermediate
	IDSA1	7.04(0.35)	2.55(0.14)	2.76	Long	Intermediate
	IR841	6.83(0.27)	2.69(0.20)	2.54	Long	Intermediate
	TOX LONG	5.93(0.37)	2.50(0.21)	2.37	Medium	Intermediate
	Mean	6.72	2.54	2.73	–	–
Newly developed varieties	NERICA1	6.85(0.33)	2.56(0.12)	2.68	Long	Intermediate
	NERICA3	7.33(0.21)	2.50(0.07)	2.93	Long	Intermediate
	NERICA4	7.19(0.14)	2.52(0.08)	2.85	Long	Intermediate
	NERICA6	6.19(0.25)	2.83(0.07)	2.19	Medium	Intermediate
	NERICA7	7.33(0.13)	2.61(0.07)	2.81	Long	Intermediate
	Mean	6.97	2.60	2.69	–	–

Values in the brackets are the Standard Deviation.
Within columns, differences between two means exceeding twice this value are significantly different at $p < 0.05$.

2.2.13. *Statistical data analysis*

The data obtained were analyzed using analysis of variance (ANOVA) processed with (SAS 9.2) at a 95% confidence level. Descriptive statistic was used for grain dimension analysis. Means separation was carried out by least significant difference (LSD). Hierarchical clusters have been performed using SPSS 16.0.

3. Results and discussion

Rice grain quality is premised on physicochemical properties which are greatly influenced by genotype (Kishine, Suzuki, Nakamura, & Ohtsubo, 2008). The physical appearance of milled rice is important to the consumer, which in turn makes it important to the marketer and the miller. Grain size and shape are among the first rice quality criteria that breeders consider when developing new varieties for release and for commercial production (Rani, Pandey, Prasad, & Sudharshan, 2006). Preferences for grain size and shape vary from one group of consumers to another (Rani et al., 2006). Length to Width (*L/W*) ratios are used in the classification of grain shape, a higher value indicating slender shapes and a lower value indicating medium intermediate, bold or round shapes. In this study, the mean *L/W* ratio was higher (3.51) for imported varieties compared to the previously cultivated varieties (2.73) and the newly developed varieties (2.69). Based on the AfricaRice (ex-WARDA classification (1995), all the imported varieties had slender shapes while all the previously cultivated and newly developed varieties had medium shapes (Table 2). The presence of chalkiness in rice grain has been described as a "defect" that affects milling, marketing and storage properties (Adu-Kwarten, Ellis, Oduro, & Manful, 2003). The imported rice varieties had low chalkiness scores (0–1). The chalkiness scores of the previously cultivated and newly developed varieties were higher. Except for ADNY 11 which chalkiness score was 1, the other previously cultivated varieties had chalkiness scores of between 4 and 5 while all the newly developed varieties had a chalkiness score of 4 (Table 3). Rice grain hardness is important in many areas of the rice industry and numerous studies on this subject have been reviewed in considerable detail (Pomeranz & Web, 1985). Grain hardness is an important factor in such diverse areas as

Table 3
Physico- chemical characteristics of selected varieties.

Grouping	Varieties	Chalkiness score	Hardness (kg)	% Whiteness	% Translucency	% Protein	% Amylose
Imported rice	ELEPHANT	1	7.6^{bcd}	70.8^{b}	3.0^{efg}	7.2^{bc}	23.4^{abcd}
	GINO	0	7.7^{abc}	66.2^{e}	3.4^{bc}	6.4^{c}	23.4^{abcd}
	SAVANA	1	7.2^{bcde}	62.5^{h}	3.6^{ab}	7.4^{b}	22.7^{bcd}
	SPECIAL RICE	1	7.0^{cdef}	63.4^{gh}	3.4^{bc}	7.3^{bc}	23.0^{abcd}
	SULTANA	1	8.3^{ab}	64.7^{fg}	3.7^{a}	7.0^{bc}	23.6^{abcd}
Previously cultivated varieties	ADNY 11	1	8.9^{a}	60.7^{i}	2.5^{ij}	7.7^{b}	22.9^{bcd}
	BERIS 21	5	5.5^{g}	65.7^{ef}	2.4^{j}	7.1^{bc}	22.7^{bcd}
	IDSA1	5	6.1^{efg}	68.7^{cd}	3.4^{bc}	7.1^{bc}	21.2^{e}
	IR841	4	8.1^{abc}	63.2^{h}	2.9^{fgh}	7.4^{b}	23.1^{abcd}
	TOX LONG	5	7.6^{bcd}	74.6^{a}	1.2^{k}	6.8^{bc}	22.6^{cd}
Newly developed Varieties	NERICA1	4	7.2^{bcde}	73.2^{a}	2.7^{hi}	10.6^{a}	23.8^{abc}
	NERICA3	4	6.5^{defg}	71.3^{b}	2.8^{gh}	10.5^{a}	23.8^{abc}
	NERICA4	4	5.9^{fg}	65.3^{ef}	3.3^{cd}	10.6^{a}	22.8^{bcd}
	NERICA6	4	6.1^{efg}	68.0^{d}	3.1^{def}	10.7^{a}	22.5^{d}
	NERICA7	4	5.9^{fg}	70.0^{bc}	3.2^{cde}	10.8^{a}	24.1^{a}
	LSD (5%)	–	1.22	1.43	0.25	0.9	1.1

Means with the same alphabet as superscript within columns are not significantly different at 5%.

Table 4
Cooked rice characteristics of selected varieties.

Grouping	Varieties	Gel consistency	Water uptake ratio	Elongation ratio	Swelling ratio	Cooking time (min)
Imported rice	ELEPHANT	100.0^{a}	2.074^{hi}	1.593^{bc}	4.073^{def}	17.3^{de}
	GINO	99.5^{a}	2.221^{fg}	1.453^{h}	4.933^{a}	19.6^{c}
	SAVANA	100.0^{a}	2.191^{fgh}	1.567^{bcd}	3.835^{f}	19.3^{cd}
	SPECIAL RICE	99.3^{a}	2.420^{cd}	1.490^{gh}	4.364^{bde}	19.0^{cde}
	SULTANA	99.3^{a}	2.018^{ij}	1.539^{defg}	4.217^{cde}	17.0^{e}
Previously cultivated varieties	ADNY11	100.0^{a}	2.289^{ef}	1.503^{gh}	4.117^{def}	18.6^{cde}
	BERIS 21	71.3^{b}	2.516^{bc}	1.504^{fgh}	4.260^{bcde}	25.6^{a}
	IDSA1	66.8^{b}	2.386^{de}	1.512^{efg}	4.045^{ef}	22.3^{b}
	IR841	63.0^{b}	2.610^{ab}	1.564^{bcde}	4.132^{def}	23.3^{b}
	TOX LONG	71.3^{b}	2.690^{a}	1.760^{a}	4.365^{bcde}	19.6^{c}
Newly developed Varieties	NERICA1	99.6^{a}	2.200^{fgh}	1.603 ^{b}	4.202^{cde}	26.0^{a}
	NERICA3	99.0^{a}	1.895^{j}	1.556^{bcdef}	4.401^{bcd}	22.0^{b}
	NERICA4	99.1^{a}	2.100^{ghi}	1.532^{defg}	4.600^{ab}	24.0^{ab}
	NERICA6	98.8^{a}	2.004^{ij}	1.574^{bcd}	4.595^{ab}	23.0 ^{b}
	NERICA7	95.0^{a}	1.895^{j}	1.542^{cdefg}	4.503^{bc}	24.0^{ab}
	LSD(%5)	13.18	0.052	0.052	0.352	2.14

Means with the same alphabet as superscript within columns are not significantly different at 5%.

changes during storage and aging (Indudhara, Sowbhagya, & Bhattacharya, 1978), drying and handling (Kunze & Hall, 1965), kernel appearance and translucency (Nagato, 1962), resistance to pest and insect attacks (Peng & Hsia, 1984) and processing and grain breakage during the milling process (Goodman & Rao, 1983). Results of this study showed no discernable trends between the hardness values of the three types of varieties however; the highest (8.9 kg) and lowest (5.5 kg) values of grain hardness were recorded with the previously cultivated varieties (Table 3).

Generally, most consumers prefer white and translucent grains and are prepared to pay a premium for it (Rani et al., 2006). Similarly, results from this study showed no consistent trends among varieties with regard to their grain whiteness and translucency (Table 3).

The cooking and eating characteristics of rice are largely determined by the properties of starch that makes up 90% of the milled grain. Amylose content, gel consistency and protein content directly influence the cooking and eating qualities of milled rice (Bahmaniar & Ranjbar, 2007).Generally, rice varieties with high amylose content (over 25%) cook dry, are less tender and become hard upon cooling while those with low amylose content (below 20%) cook moist and are sticky (Dipti, Bari, & Kabir, 2003; Normita, 1978). All the varieties tested had intermediate amylose content (between 20 and 24%). NERICA7 had the highest amylose content of 24.1% while IDSA1 had the lowest amylose content of 21.2% (Table 3). The findings of this study showed that the newly developed varieties had higher protein contents (10.5–10.8%) compared to the previously cultivated varieties (6.8–7.4%) and imported varieties (6.4–7.4%). This is consistent with the results of Watanabe, Futakuchi, Jones, and Sobambo (2006). Apart from TOX LONG (6.8%) and GINO (6.4%) which had significantly lower protein contents, the remaining imported and previously cultivated varieties had similar protein contents (Table 3).

The imported and newly developed varieties all had very high gel consistencies (over 95 mm) and they were not significantly different from each other at 5% level (Table 4). For the previously cultivated varieties, ADNY had a gel consistency of 100 mm which was comparable to the imported and newly developed varieties. BERIS 21, IDSA1, IR841 and TOX LONG had significantly lower gel consistencies (71.3–63 mm) at 5% level (Table 4).

Some parameters that relate to cooked rice quality were determined. These were the water uptake ratio, elongation ratio and grain swelling ratio. Although some differences were found between individual samples, no clear patterns emerged when the groupings namely, imported varieties, previously cultivated varieties and newly developed varieties were compared (Table 4). With regards to the cooking time, the newly developed varieties had longer cooking time (22.0–26.0 min) compared to the imported varieties (17.0–19.6 min). This was expected as all the newly developed varieties had Oryza glaberrima parents which are known to have higher cooking time (Manful & Fitzgerald, 2010-unpublished). The previously cultivated varieties had greater variability in their cooking times. This ranged from 18.6 min for ADNY 11 to 25.6 min for BERIS 21(Table 4).

Fig. 1 shows the hierarchical clusters analyses for the varieties studied. With regards to the physical characteristics, the varieties can be divided into two main groups. The first group included one imported variety (ELEPHANT), three previously cultivated produced varieties (IDSA1, BERIS 21 and TOX LONG) and five newly

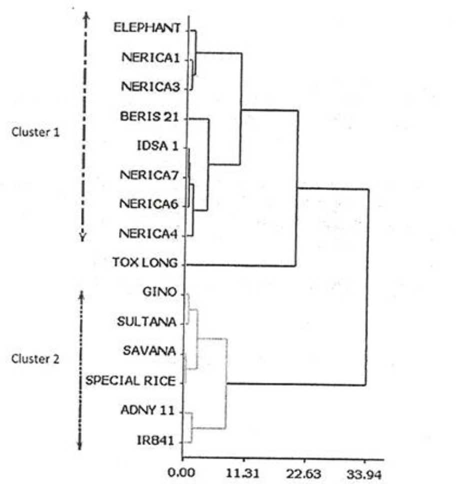

Fig. 1. Hierarchical cluster showing varietal groupings according to physical characteristics of grains.

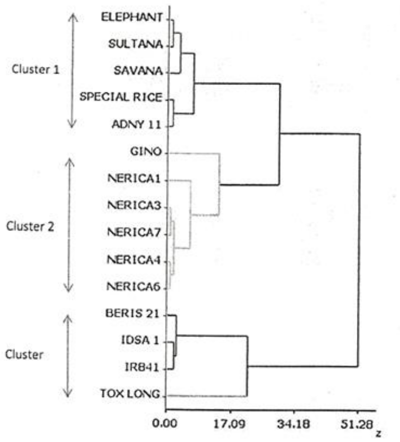

Fig. 2. Hierarchical cluster showing varietal groupings according to cooked grain characteristics.

developed varieties (NERICA1, NERICA3, NERICA4, NERICA6, NERICA7). The second group comprises two previously cultivated varieties (IR841, ADNY 11) and four imported varieties (GINO, SULTANA, SAVANA, SPECIAL RICE). With regards to the cooking characteristics, the hierarchical cluster showed three main groups (Fig. 2). The first group included four imported rice varieties (ELEPHANT, SULTANA, SAVANA, and SPECIAL RICE) and one previously cultivated variety (ADNY11), the second group comprised one imported variety (GINO) and four newly developed varieties (NERICA3, NERICA4, NERICA6, NERICA7). The third group comprised of only previously cultivated varieties (BERIS 21, IDSA1, IR841, TOX LONG). From these two hierarchical clusters, it is clear some previously cultivated varieties and some newly developed NERICA varieties have some similarities in their grains qualities.

4. Conclusions

There were significant differences among the three groups of varieties for most of the parameters measured. While all the imported varieties had long and slender grains, the previously cultivated and newly developed varieties had mainly intermediate shapes. The imported varieties also had lower chalkiness scores and shorter cooking times compared to the others. Protein content was higher in the newly developed varieties which will be particularly attractive for dissemination in parts of West Africa with high incidence of protein malnutrition. The amylose content of the all the varieties studied fell within the range preferred by many consumers in West Africa (20–25%). The rice grain characteristics studied in this paper are important to most consumers in West Africa and will provide a guide to breeders seeking to develop varieties acceptable to rice consumers in this sub-region.

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