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Research Paper

Rice grain quality: a comparison of some local varieties with improved varieties in Eastern DR Congo

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ABSTRACT
In recent decades, rice (Oryza sativa *L.) has become a very important foodstuff in sub-Saharan Africa. In South Kivu in the east of DR Congo, consumers prefer imported rice to local rice generally because of its culinary and nutritional qualities. This work is part of the dynamic of comparing improved varieties to locally produced varieties. Four (4) varieties of improved rice: RPR2109, RPR2110, RPR2123, RPR2133 were compared to 4 locally produced varieties: V046, Komboka , Fashingabo , Mugwiza . The results obtained show that there is a significant difference between the physicochemical and culinary characteristics of the two types of varieties. Grain size and shape, endosperm appearance and milling quality were better in new improved varieties than in local varieties (p<0.05). The latter would better meet the needs of the population. However, local varieties have the best milling characteristics and texture after cooking, making them good sources of donor parents in rice breeding programs.*

Keywords: *Rice, physical quality, nutritional value, South Kivu*

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I. Introduction

Like several sub-Saharan countries, Rice is an important crop in Democratic Republic of Congo, with a steady increase in consumption over recent decades due to population growth, urbanization, and changes in consumer habits.

Rice research in the country has focused on the production of improved varieties with better production yields, and stress resistance. However, there is a paucity of data on physical properties, nutrient composition, sensory attributes, and processing characteristics of the different rice varieties being cultivated by farmers in the country.

The objective of this study was to assess the physical and nutrient variations between the improved and the local varieties.

II. Materials and methods

2.1 Material source

Twelve rice varieties were evaluated: 8 local collections, 4 improved varieties from Rwanda Agriculture Board (RAB), and 4 local varieties from National Institute for Agronomic Study and Research (INERA) of Democratic Republic of Congo (Table 1). In this study, each trait was measured in triplicate.

Table 1: List of rice varieties

Grouping	Name	Source
Improved varieties	RPR109	RAB
	RPR110	RAB
	RPR123	RAB
	RPR133	RAB
Local varieties	V046	INERA
	Komboka	INERA
	Fashingabo	INERA
	Mugwiza	INERA

2. 2 Sample preparation

Enough paddy of each variety, moisture content 14%, were dehusked in a Satake Testing Rice Husker (THU-34A, Satake Co. Ltd. Tokyo, Japan). The brown rice obtained was polished in a single pass rice pearler (BS08A Satake Co. Ltd. Tokyo, Japan). Samples were stored in plastic containers prior to analysis.

2.3. Physical measurements

2.3.1. Grain size and shape

The length and width of 10 whole polished grains were measured using a micrometer screw gauge with accuracy of 0.01 mm. Data obtained were interpreted based on the scale described by WARDA (1995).

2.3.2. Thousand grain weight

Consist in the counting and weighing of 100 randomly selected unmilled kernels. The weight obtained was multiplied by 10 to determine the thousand grain weight.

2.3.3. Total milling recovery (TMR)

This is the weight of total milled rice obtained from a known weight of paddy expressed as a percentage after dehulling and polishing (WARDA, 1995).

2.3.4. Broken fraction

This was determined by weighing 100 g of polished rice and separating into broken and unbroken fractions. This was done manually using a perforated metal sheet combined with meticulous hand picking and re-picking. Each fraction was weighed and expressed as a percentage of initial weight of rice.

2.3.5. Endosperm appearance (chalkiness)

Endosperm appearance (chalkiness)

Twenty grams samples were weighed into small flat trays mixed thoroughly and divided into four portions by means of a quartering device. Rice grains in each quarter were examined for presence of opaque or chalky portions. These were separated manually and weighed. The weight obtained was expressed as a percentage of the total weight within the quarter. The values obtained for each quarter were averaged and used to score for appearance description based on the IRTP system (1988).

2.4. Nutritional measurements

Samples were ground into fine flour prior to analyses. Total protein and ash were measured based on the Official Methods of Analysis (AOAC, 1990).

2.4.1. Water-soluble proteins

Two grams of flour sample was dispersed in 80 ml distilled water for 2 h at room temperature by continuous stirring. The suspension was filtered using Whatmans No. 42 filter paper after making volume to 100 ml. Twenty milliliters of filtrate was taken for protein determination by the Micro-Kjeldahl method (AACC, 1976).

2.4.2. Amylose

To obtain Amylose content100 mg of flour sample was added 1 ml ethanol (95%) and 9 ml 1N NaOH. The sample was heated for 10 min in boiling water bath to gelatinize starch. Sample was cooled and transferred to 100 ml volumetric flask. 5 ml of starch solution and 1 ml 1 N acetic acid added. Two milliliters of iodine solution (0.2% of re-sublimed iodine in 2% potassium iodide) was added and volume made up to 100 ml. Flask was shaken and allowed to stand for 20 min. Percent transmittance was measured at 620 nm using an Ultraspec spectrophotometer (Ultraspec Plus, model 4054, Pharmacia LICB Biochrom Ltd., England). Total amylose content of sample was determined from a previously calibrated standard amylose (Potato, Sigma) curve (Juliano, 1971).

2.4.3 Minerals

Samples were ashed and the ash wetted with 1–2 drops of distilled water and dissolved in 20 ml 1 M HCl. They were then heated, cooled, and transferred into 100 ml volumetric flask by filtering using Whatman No. 2 filter paper. Crucibles were washed twice with 5 ml distilled water and contents made to the 100 ml mark. Sodium, potassium, and calcium contents in samples were determined using a flame photometer (model ANA-10 Kl, Ogawa Seiki Company Ltd., Tokyo, Japan). Concentrations for each element were determined from previously calibrated standard curves.

2.5. Statistical analysis

The Excel version 2019 program was used for encoding and arranging data. Analysis of variance (ANOVA) was performed with R software version 4.1.3, to compare means between quantitative variables.

III. Results And Discussions

Grain size and shape of rice varieties

Table 2: Size and shape of rice grains

Grouping	Variety	Length (mm)	Width (mm)	L /W	Size description	Shape description
Improved variety	RPR109	6.80 (0.4)	2.19 (0.20)	3.11	Long	Slender
	RPR110	7.05 (0.5)	2.02 (0.10)	3.49	Long	Slender
	RPR123	7.10 (0.4)	2.50 (0.20)	2.84	Long	Slender
	RPR123	6.67 (0.6)	2.00 (0.40)	3.34	Long	Slender
	Mean	6.91	2.24	3.15	-	-
	S.E. [a]	0.06	0.05	0.02	-	-
Local varieties	V046	5.80 (0.33)	3.90 (0.40)	1.49	Medium	bold
	Komboka	7.02 (0.42)	2.85 (0.40)	2.51	Long	Slender
	Fashingabo	7.00 (0.27)	2.70 (0.30)	2.59	Long	Slender
	Mugwiza	6.88 (0.70)	2.50 (0.15)	2.75	Long	Slender
	Mean	6.94	2.82	2.47	-	-
	S.E.	0.04	0.90	0.09	-	-

1. SE = Standard error —within columns, differences between two means exceeding twice this value are significantly different at p < 0:05.
2. In brackets = Coefficient of variation of the three measurements of each trait

Grain lengths are used in the classification of grain size, grains with length less than 5.50 mm are classified as short, grains with length in between 5.50 mm and 5.90 mm are classified as medium, and grains with length higher than 5.90 mm are classified as long (Fofana *et al*, 2011). In this study, all the varieties had long grains excepted V046. In other side, Lenth 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. The mean L/W was higher (3.15) for Improved varieties and lower (2.47) for the local varieties. Based on the WARDA (1995) all the tested varieties had slender shapes except V046, which was (Table 2). Local varieties collected in INERA were breed in neighboring countries (Burundi and Rwanda) where they are considered as improved varieties this explain why grain shape and size for all studied varieties are similar. According to INERA researchers, V046 was developed in Madagascar by FOFIFA, the national breeding program, this may explain it difference from other Varieties.

Milling and chalkiness qualities of rice varieties

Table 3: Milling recovery, Broken fraction, thousand grains weight and chalkiness.

Grouping	Variety	TMR (%)[a]	Broken fraction (%)	Thousand grains weight (g)	Chalkiness score
Improved variety	RPR109	69.0 (0.82)	57.3 (0.68)	28.3 (0.52)	1
	RPR110	68.4 (1.85)	36.0 (0.92)	28.2 (0.66)	1
	RPR123	62.5 (0.70)	42.7 (1.00)	22.2 (0.41)	1
	RPR133	68.0 (1.02)	56.3 (0.96)	28.8 (0.34)	0
	Mean	66.98	38.08	26.14	-
	S.E. [a]	1.60	2.78	0.74	-
Local varieties	V046	64.01(1.85)	38.7 (0.26)	27.0 (0.25)	5
	Komboka	68.4 (1.70)	31.2 (0.24)	30.0 (0.30)	0
	Fashingabo	67.5 (2.90)	27.0 (0.19)	32.2 (0.45)	1

	Mugwiza	69.12(0.90)	23.5 (0.23)	32.3 (1.40)	1
					-
	Mean	67.23	30.10	30.38	
	S.E. [a]	1.54	1.89	0.90	

1. SE = Standard error —within columns, differences between two means exceeding twice this value are significantly different at p < 0:05.
2. In brackets = Coefficient of variation of the three measurements of each trait

Total milling recovery (TMR) is a measure of milling quality and hence economic value; a 50% or less is undesirable since it means 50% of the rice is discarded as husk and bran after milling (Fofana *et al*, 2010). The improved varieties had a mean TMR of 66.98% while the local varieties had a mean of 67.23% (Table 3). Although improved varieties had higher levels of brokens than the local varieties, all varieties in the study gave appreciably higher milling recoveries (>60%).

The presence of chalkiness in rice grain has been described as a ‘‘defect’’ that affects milling, marketing, and storage properties (Indudhara Swamy & Bhattacharya, 1982). All the varieties had no chalkiness (score: 0) except V046 which had moderately widespread chalky portions (score: 5; 10–20%) (Table 3). The low level of chalky explains the high percentage of head rice (TMR) for both local and improved varieties.

In general, TGW is a measure of seed size and a range of 20 – 30 g is acceptable, below 20 g indicates the presence of immature, damaged or unfilled grains. (Adu-Kwarteng *et al*, 2003). In this study, the thousand grain weights (TGW) of all the varieties were acceptable (>20 g). The local varieties had appreciably higher TGW (32.30g for local varieties vs 26.14 g for improved varieties).

Table 4: Total protein, water soluble proteins, amylose and Ash content

Grouping	Variety	Total protein (%)	WSP [a] (%)	Amylose (%)	Ash (%)
Improved varieties	RPR109	8.03 (0.02)	0.32 (0.03)	29.01 (0.31)	0.50 (0.06)
	RPR110	6.11 (0.12)	0.25 (0.02)	26.52 (0.04)	0.55 (0.04)
	RPR123	8.23 (0.02)	0.35 (0.08)	30.12 (0.83)	0.45 (0.05)
	RPR133	7.76 (0.13)	0.21 (0.05)	30.78 (0.03)	0.51 (0.02)
	Mean	7.53	0.28	27.20	0.50
	S.E. [a]	0.33	0.03	0.90	0.02
Local varieties	V046	6.78 (0.83)	0.21 (0.08)	21.16 (0.38)	0.53 (0.01)
	Komboka	7.19 (0.23)	0.34 (0.02)	24.17 (0.52)	0.48 (0.07)
	Fashingabo	8.12 (0.27)	0.39 (0.05)	23.54 (0.24)	0.54 (0.6)
	Mugwiza	8.27 (0.45)	0.34 (0.04)	23.13 (0.84)	0.58 (0.1)
	Mean	7.59	0.28	23.00	0.53
	S.E.	0.30	0.06	0.85	0.04

1. SE = Standard error —within columns, differences between two means exceeding twice this value are significantly different at p < 0:05.
2. In brackets = Coefficient of variation of the three measurements of each trait

Table 5: Potassium, calcium, and Phosphorus content

Grouping	Variety	Potassium (mg/100g)	Calcium (mg/100g)	Phosphorus (mg/100g)
Improved varieties	RPR109	85.49 (0.99)	21.42 (0.40)	170.45 (1.25)
	RPR110	56.71 (1.01)	22.08 (0.32)	134.61 (1.80)
	RPR123	71.18 (1.30)	19.25 (0.66)	183.35 (1.41)
	RPR133	94.44 (1.60)	21.60 (0.72)	189.87 (0.97)
	Mean	85.44	21.09	167.98
	S.E. [a]	0.33	0.08	0.20
Local varieties	V046	20.63 (0.82)	23.27 (0.79)	160.23 (1.50)
	Komboka	81.37 (1.00)	28.00 (0.88)	116.54 (2.00)
	Fashingabo	80.89 (1.50)	25.53 (0.95)	135.62 (1.20)
	Mugwiza	80.78 (1.20)	24.23 (0.62)	141.54 (1.45)
	Mean	65.92	25.26	131.74
	S.E. [a]	0.35	0.10	0.22

1. SE = Standard error —within columns, differences between two means exceeding twice this value are significantly different at p < 0:05.
2. In brackets = Coefficient of variation of the three measurements of each trait

Protein, a key factor influencing the eating quality of rice (Horino *et al*, 1983) was high (> 7 %) for all the varieties except for RPR110 (Table 4). Significant differences (p < 0:05) existed in the protein contents with the local varieties having higher levels (6.78– 8.27%) relative to the improved varieties (6.11–8.23%). The ranges obtained for the varieties fall within that for polished rice (5–14%) (Damardjati *et al*, 1985). The variations observed may be due to varietal and environmental influences. Juliano (1985) reported high levels of fertilizer increasing total protein content. Other factors such as short growth periods, soil salinity or alkalinity may also increase protein content of grain (Adu-Kwarteng *et al*, 2003). Water-soluble proteins for varieties ranged between 0.21% and 0.39% with the local varieties while it ranged between 0.21% and 0.35% for improved varieties (Table 4). There was a significant correlation between the extracted water-soluble proteins and total protein content for both the improved varieties (r ¼ 0:82) and the local varieties (r ¼ 0:92) result not showed. This implies that water-soluble protein level varies correspondingly with protein content and agrees with the findings of Adu-Kwarteng *et al*, 2003 and Fofana *et al*, 2010a.

Amylose levels were higher in the improved varietes (mean value = 27.20%) compared to the local varieties (mean value = 22.11% (Table 4). Based on the classification of Hamaker & Griffin, 1993, improved varieties are considered as high amylose content varieties while local varieties are intermediate amylose content varieties. The intermediate amylose varieties are generally most preferred because they cook dry and fluffy retaining their soft texture even after cooling (Hamaker & Griffin, 1993, Fofana *et al*, 2011b, Roseline et al 2016). The high amylose type cooks dry and fluffy but become hard on cooling (Hamaker & Griffin, 1993). This is due to retrogradation of the amylose molecules which tend to associate or bind strongly together with decreasing temperature (Hamaker & Griffin, 1993). Amylose content is an important factor in determining the cooking and pasting behavior of rice and its end use. Various workers have reported on the reliability of amylose content as a predictor of cooked rice stickiness (Juliano, 1985; Hamaker, Griffin & Moldenhauer, 1991; Fofana *et al*,2011b).

Significant differences (p < 0,05) existed in the total ash levels averaging 0.56% for the local varieties and 0.50% for the improved varieties (Table 4). The values obtained fall within the range reported by Juliano (1985) in milled rice grain (0.3–0.8%). As described by Adu-Kwarteng *et al*, 2003, the variations in ash content may be due to the degree of milling/polishing which is influenced by varietal effect. Rice bran contains much more minerals than the actual endosperm and the tendency of rice bran to stick to the grains during milling/ polishing (which is a varietal trait) influences ash content Adu-Kwarteng *et al*, 2003.

Potassium content in improved varieties ranged between 56.71–94.44 mg/ 100 g and between 20.63 – 97.78 mg/100 g for the local varieties (Table 5). These values were within the range reported by Matsuzaki, Takano & Takeda (1991) quoted by Adu-Kwarteng *et al*, 2003. In Table 5, mean Potassium levels were more pronounced among the improved varieties than the local varieties (85.44 mg/100g vs 65.92 mg/100g). This may be due to varietal effect. Potassium plays an important role in human body metabolism thus foods with appreciable amounts are beneficial to health.

For calcium levels which ranged between 18.25 and 20.27 mg/100 g for the 8 varieties (Table 5), the local varieties had appreciably higher levels relative to the improved varieties. Pederson & Eggum (1983) reported ranges of 10–30 mg/100 g for polished rice.

IV. Conclusion

There were significant differences between both the improved lines and local varieties for all the parameters studied. Grain size and shape, endosperm appearance and milling quality were better among the improved varieties than the local varieties. This is not surprising since breeding efforts are geared towards attaining grain physical characteristics that appeal to both consumers and commercial rice millers. However, the local varieties studied exhibited nutritional superiority especially potassium, calcium, and protein contents. Many of them also had acceptable milling qualities. Their amylose contents also fell within the preferred range (20 – 25%). This study showed that in eastern DR Congo, the local varieties must not be left out but given the requisite attention since they form a rich resource for incorporation into breeding programs.

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