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Research Paper

Effects of processing methods on physicochemical, functional and sensory properties of Ofada rice

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Abstract. Ofada rice samples were obtained from Ofada village in Ogun State, Nigeria. The samples were parboiled and milled using both the traditional Ofada processing (soaking for eight days) and the improved rice processing method (the hot water soaking method). A known rice variety "FARO 42" was parboiled and milled by the same methods for comparisons. The physicochemical composition, the pasting characteristics, and the acceptability of the samples were analyzed. The results showed that the protein content of Ofada rice processed by the two methods ranged from 8.26 to 9.92% with Ofada rice samples processed by the improved method having significantly ($p \leq 0.05$) higher protein (9.92%) and other proximate values than the samples from the prolonged soak method (8.26%). The milled rice samples showed that samples from prolonged soaking had lower milling returns (75.80%) compared to 79.35% for samples processed with the improved method. Prolonged soaking also led to significant ($P \leq 0.05$) decreases in the pasting values of the Ofada samples. The sensory analysis showed that there were no significant ($p \leq 0.05$) differences in the taste of Ofada and FARO 42 samples processed by the prolonged soaking method. These however differed significantly ($p \leq 0.05$) from samples of the improved method and commercial rice sample. The results suggested that the acclaimed Ofada taste and aroma may not be generic after all.

Keywords: Ofada rice, Faro 46 processing methods, physico-chemical properties, sensory properties.

INTRODUCTION

Rice is the staple food for over 3 billion people, constituting over half of the world's population (Ebuehi and Oyewole, 2007). According to Itani et al. (2002), rice is ranked as the world's number one human food crop.

Anuonye et al. (2007) reports that Ofada is a generic name used to describe rice produced and processed in the rice producing cluster of the South-West Nigeria. According to them Ofada is planted mostly in Ogun State and some other rice producing areas in South-Western Nigeria such as Lagos and Ekiti. In these places, every rice seed planted is taken to be 'Ofada' rice. Ofada rice brand popularity is associated with its characteristics taste, aroma mouth-filling, red coated grains that is in its unpolished form.

Cooked Ofada rice is a special delicacy eaten occasionally by natives of this region and traditionally served in *Tomatococeus danielli* leaves with a special kind of sauce prepared using pepper (Atarodo, Tatase), onion, locust beans, palm oil and assorted meat. Ofada rice brand popularity is associated with its characteristics taste, aroma mouth-filling, red coated grains that is in its unpolished form. The common belief is that Ofada may be aromatic rice in the mould of basmati rice. This claim became obvious during the presentation of the Ofada rice genetic identity in Abeokuta, Ogun State, Nigeria in 2007(Anuonye et al., 2007).

Rice soaking before parboiling is akin to the initial phase of germination, when large amount of enzymatic

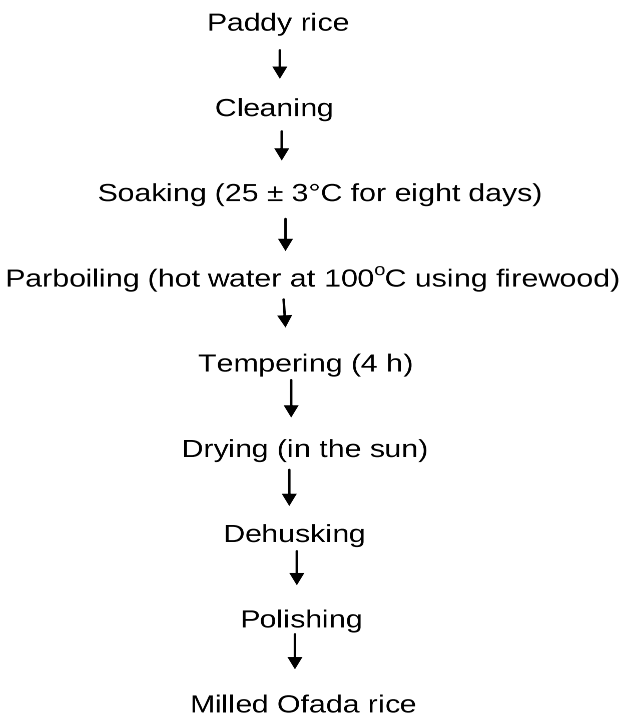

Figure 1. Flow chart for traditional Ofada rice processing. Source: Personal communications Ofada Rice Village, Ogun State.

activities take place. In view of possible natural contamination, a great deal of microbial action is expected during soaking. Fermentation during the traditional parboiling has been studied (Bhattacharya, 1985) and the fermented odour could be eliminated if the soaking is in hot water. However, for Ofada rice parboiling, soaking is done in cold water for about eight days. It is therefore suspected that the peculiar Ofada odour and taste may be due to microbial fermentation activities. This work was carried out to evaluate the effect of improved processing methods on milled Ofada rice quality.

MATERIALS AND METHODS

The Ofada paddy rice was purchased from Ofada Village in Ogun State. Ofada rice and check (FARO 42) were subjected to both the local methods adopted for Ofada rice parboiling at the Ofada village in Ogun State, Nigeria (Figure 1) according to personal communications with Ofada rice processors in the Ofada village. The improved rice parboiling method reported by the National Cereals Research Institute (NCRI) (2006) (Figure 2) was used to produce similar samples for comparison. All the processing and analysis were carried out at the Rice Processing Laboratory of the National Cereals Research Institute (NCRI), Badeggi, Niger State.

Analysis

Rice physicochemical characteristics

Grain length, width and shape, weight of 1000 whole grains were evaluated using the Standard Evaluation System (SES) for rice International Rice Research Institute (IRRI, 1996).

The percentage head rice, percentage broken grain and hull were determined using the method of IRRI (1996).

The moisture content, the protein the fat, the fiber the ash and energy contents of the samples were determined according to the Association of Official Analytical Chemists (AOAC 2000). The energy value was calculated using this relationship Energy value (Kcal/100 g) = (4 × protein) + (9 × fat) + (4 × carbohydrate).

Dehusked raw grain (whole grains) weighing 100 g was transferred to a measuring cylinder. Distilled water (100 ml) was added. Grain volume was obtained after subtracting 100 ml from the final volume (ml). Density was then calculated as g/ml according to Bishnoi and Khetarpaul (1993).

Cooking and eating characteristics

The cooking time was determined by the procedure reported by Bishnoi and Khetarpaul (1993) while solid in cooking water, grain volume expansion, and grain elongation were determined as reported by Juliano (1985).

Amylose content

Amylose content was evaluated by the method of Cruz and Khush (2000).

Pasting characteristics

Pasting profile of the samples was evaluated using the 20 min – Rapid Visco- Analyser (RVA) (Newport Scientific 910140, Sydney Australia) as reported by Anuonye et al. (2007).

Mineral analysis

The mineral content of Ofada samples and check was

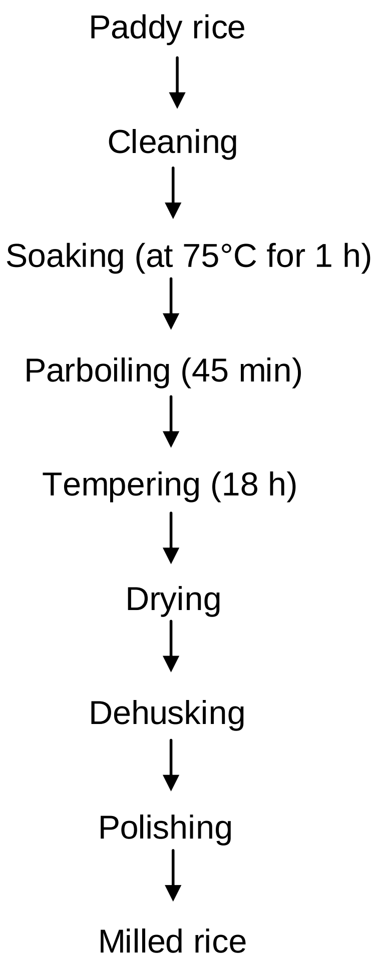

Figure 2. Flow chart for improved method (milled rice processed) (NCRI, 2006).

determined on Buck 210 Atomic Absorption Spectrophotometer (made in Germany) according to AOAC (2000).

Sensory evaluation

Sensory evaluation of the cooked Ofada rice samples with control was carried out by a semi-trained panel in a special room prepared for the purpose according to Ebuehi and Oyewole (2004).

Statistical analysis

All data were subjected to statistical analysis of variance (ANOVA). Means of significant differences were separated by Duncan's Multiple Range Test (2000).

RESULTS AND DISCUSSION

Physicochemical properties

The moisture content of milled Ofada samples and the control is presented in Table 1. Moisture content varied between 8.24 to 10.21 g/100 g. Jamila et al. (2015) reported that moisture content is an important quality index of grains and that moisture content ranging from 9 to 11 g/100 g, is safe for storing milled grains. William (1990) also reported that the optimum moisture content for storage lies between 12 and 14%, which influences some other quality characteristics such as cooking quality and storage period. Dhaliwal et al. (1991) reported that moisture content of IR-8 PR-108 and Basmati-370 varied from 12.4-13.1 to 14-15.4% for dried and non dried samples after one month of harvest. The values obtained for moisture content in this present study for both Ofada samples processed by the prolonged soaking method and the improved methods were within these reported ranges though Ofada samples of prolonged soaking had significantly ($P \leq 0.05$) higher moisture content.

The results showed that the improved processing method yielded milled rice with higher proximate values. This was expected as the prolonged soaking periods resulted in significant ($P \leq 0.05$) nutrient leaching into the soaked water. The significant ($P \leq 0.05$) reductions in the fat, protein, carbohydrate and energy values of samples soaked for eight days with and without changing the water confirmed the reports of Abulude (2004) and El-Qudah (2008) that water soluble nutrients move into the soak water during soaking forcing fat and other nutrient to move out. Ebuehi and Oyewole (2004) have also shown that soaking causes protein bodies to sink into the compact mass of gelatinized starch making it less extractable. Joseph (2015) had reported that the protein content of some African rice varieties ranged from 7.22 to 11.29% while its Asian counterparts ranged from 5.00 to 6.69%. The results obtained in the current work were within the range reported for African rice and higher than the values reported for Asian rice varieties in spite of the method of processing followed.

The results of the functional properties of the rice samples (Table 2) showed that the samples soaked for eight days with or without changing of water had significantly ($P \leq 0.05$) lower values for all functional parameter evaluated.

According to Lawal et al. (2011), the swelling capacity is a measure of the ability of starch to hydrate under specific conditions such as temperature and water availability. Starch swelling occurs alongside loss of

Table 1. Proximate composition of samples processed by the prolonged soaking and improved methods.

Samples	Proximate parameters						
	Moisture	Ash	Fat	Protein	CHO	Fiber	Energy
A	8.31 ± 1.67[b]	1.66 ± 0.28[a]	0.43 ± 0.03[b]	0.22 ± 0.03[a]	7.09 ± 0.20[b]	82.79 ± 1.63[a]	361.32 ± 5.45[b]
B	10.01 ± 0.18[ab]	1.17 ± 0.29[b]	0.51 ± 0.41[b]	0.10 ± 0.05[b]	7.35 ± 1.01[b]	80.96 ± 1.31[a]	357.72 ± 1.14[b]
C	9.53 ± 0.18[ab]	1.67 ± 0.29[b]	0.43 ± 0.25[b]	0.08 ± 0.02[b]	8.26 ± 1.07[b]	80.58 ± 1.31[a]	359.26 ± 0.75[b]
D	10.24 ± 0.43[a]	1.78 ± 0.25[a]	3.39 ± 0.30[a]	0.10 ± 0.05[b]	9.92 ± 0.22[a]	74.67 ± 0.42[b]	368.80 ± 2.74[a]

A = FARO 42 soaked for eight days without changing the water (traditional Ofada rice processing).
B = Ofada rice soaked for eight days without changing the water (traditional Ofada rice processing).
C = Ofada rice soaked for eight days with changing of water every day.
D = Ofada rice soaked overnight in hot water (improved processing method).

Table 2. Physical and Functional Parameters of samples subjected to prolonged soaking and improved methods of processing.

Samples	Parameters evaluated								
	MR (%)	WG (%)	BG (%)	L (mm)	W (mm)	L/W	BD (g/ml)	SC (%)	S (%)
A	64.36	15.85±2.00[b]	3.38±2.00[a]	7.13±0.25[a]	2.03±0.58[b]	3.51±0.42[a]	0.68±0.02[a]	0.01±0.0[b]	0.48±0.0[b]
B	75.80	19.39±2.00[b]	0.11±0.02[b]	5.93±0.29[b]	2.43±0.25a	2.44±0.15[b]	0.69±0.02[a]	0.01±0.0[b]	0.57±0.0[b]
C	77.00	19.37±0.90[b]	0.28±0.06[b]	6.03±0.12[b]	2.57±0.12[a]	2.34±0.15[b]	0.71±0.01[a]	0.01±0.0[b]	0.00±0.0[c]
D	79.35	19.49±1.00[a]	0.09±0.03[b]	6.20±0.62[b]	2.57±0.15[a]	2.41±0.15[b]	0.70±0.01[a]	0.02±0.0[a]	1.09±0.0[a]

Key:
A = FARO 42 soaked for eight days without changing the water (traditional Ofada rice processing).
B = Ofada rice soaked for eight days without changing the water (traditional Ofada rice processing).
C = Ofada rice soaked for eight days with changing of water every day
D = Ofada rice soaked overnight in hot water (improved processing method).
MR = Milling Recovery; WG = Whole Grain; BG = Broken Grains; L = Grain Length; W = Grain Width; L/W=Length/Width ratio; BD = Bulk Density; SC = Swelling Capacity; S = Solubility.

birefringence and precedes solubilization (Singh et al., 2004). The results obtained for Ofada samples subjected to prolonged soaking with or without changing the soak water were below 12.25 and 18.56 ml/g reported for two African rice cultivars by Falade et al. (2014). However the solubility values reported for these cultivars agreed with the values reported in this present work. Joseph (2015), Mir and Bosco (2014) and Sodhi and Singh (2003) had explained that variations in swelling power and solubility of starch among different cultivars of rice may be attributed to the differences in amylose content, molecular weight of amylose and amylopectin, viscosity patterns, phosphate groups and bonding forces within the starch granules. However the swelling power values of 11.4 to 23.5 ml/g reported by Tan and Corke (2002) for sixty-three non waxy starches were similar to the values obtained for rice starch from the improved processing method.

Xiangli et al. (2015) reported that waxy or low-amylose rice starches exhibited relatively higher swelling power than high-amylose starches, whereas the latter showed a higher water solubility index. The results obtained are in agreement with these explanations as it affects intermediate amylose rice grains. The lower swelling power and water absorption capacity of the samples of prolonged soaking is attributable to maximum hydration of the kernel during the soak period.

The bulk densities were lower compared to the values (0.86 to 0.90 g/ml) reported by Joseph (2015) and Singh et al. (2005) for African and Asian rice kernel. The length: width ratios were however close to the values (1.71:3.56) reported for Africa rice (Joseph, 2015). Comparing the check to the Ofada samples however, the length to width ratio was statistically ($P < 0.05$) different showing differences in the size (length) and shape (slender) between the check and Ofada samples. Fofana et al. (2011) had reported slender shape with length to width ratio of 3.51 mm among imported rice varieties in Benin Republic while improved rice varieties were reported to have medium shape with length to width ratio of 2.69. The results obtained in this study for prolonged soaking and improved processing methods showed that the check FARO 46 had length to width ratio of 3.51 corresponding to the slender shape while the Ofada samples irrespective of processing method had length to width ratio between 2.35 and 2.44 corresponding to the medium

Table 3. Cooking characteristics of samples of prolonged soaking and improved methods.

Samples	Parameters evaluated					
	CTime (min)	SW (%)	VE ($m^{3)}$)	WA (mg)	GE (Lmm)	GEW (mm)
A	18.67 ± 0.58^{c}	0.40 ± 0.01^{b}	1.83 ± 0.12^{b}	1731 ± 102.30^{b}	2.23 ± 0.06^{a}	1.30 ± 0.01^{a}
B	21.00 ± 0.00^{b}	0.23 ± 0.06^{b}	1.87 ± 0.12^{b}	1651 ± 124.10^{b}	1.80 ± 0.10^{b}	1.27 ± 0.06^{a}
C	21.33 ± 0.58^{b}	0.27 ± 0.06^{b}	1.80 ± 0.17^{b}	1950 ± 108.14^{a}	1.40 ± 0.10^{c}	0.87 ± 0.15^{b}
D	22.00 ± 0.00^{a}	0.04 ± 0.02^{a}	2.10 ± 0.10^{a}	1651 ± 124.84^{b}	1.80 ± 0.01^{b}	0.87 ± 0.06^{b}

Key
A = FARO 42 soaked for eight days without changing the water (traditional Ofada rice processing).
B = Ofada rice soaked for eight days without changing the water (traditional Ofada rice processing).
C = Ofada rice soaked for eight days with changing of water every day.
D = Ofada rice soaked overnight in hot water (improved processing method).
CT = Coking Time; SW = Solid in Water; VE = Volume Expansion; WA = Water Absorption; GEL = Grain Elongation Length; GEW = Grain Elongation Width.

Table 4. Apparent amylose content of samples of prolonged soak and improved methods.

Samples	Amylose content (%)
A	14.00^{a}
B	11.90^{b}
C	11.70^{b}
D	11.40^{b}

Key:
A = FARO 42 soaked for eight days without changing the water (traditional Ofada rice processing).
B = Ofada rice soaked for eight days without changing the soak water (traditional Ofada processing)
C = Ofada rice soaked for eight days with changing of water every day
D = Ofada rice soaked overnight in hot water (improved processing method).

shape. Joseph (2015) explained that the grain length and shape of rice are important characteristics to consumers because they determine the physical appearance and affect the cooking quality of the grain. In relation to head rice recovery, Table 3 showed that samples of prolonged soaking had lower head rice recovery values especially the check FARO 46. This is attributable to the slender shape of the sample as shown by the length/width ratio.

Cooking characteristics

Danbaba et al*.* (2011) reported that cooking time for rice is the time when 90% of the starch in the grain no longer show the opaque center when pressed between two glass plates. Rice differs in optimum cooking time in excess water between 15 to 25 min without pre-soaking (Juliano et al., 1981). Danbaba et al. (2011) reported that Ofada rice samples cook between 17 to 24 min, and on the average 20.80 min. Joseph (2015) reported that optimum cooking time for African and Asian rice cultivars varied between 17 to 21 min and 17.0 to 23 min respectively, while total solids lost were between 2.96 and 5% for African Rice cultivars and between 4.33 and 6.04% for Asian cultivars. The results of this work (Table 4) are in agreement with these reports. However, the results indicated that prolonged soaked samples had higher grain length and width expansion, higher solids lost and lower volume expansion.

Zhang et al. (2010) and Futakuchi and Sié (2009) reported that the content of amylose in rice is a major factor that affects texture and taste of cooked rice hence high amylose concentration upon cooking exhibits high volume expansion, becomes less tender and harder when it cools while low amylose rice cooks moist and sticky (Juliano, 1985). Leaching as a result of prolonged soaking affected the Ofada samples hence the general reductions in the values of cooking parameters measured.

Amylose content

The results of amylose content of prolonged soaked and improved method samples (Table 4) showed that there was no significant ($P \geq 0.05$) difference in the amylose content of the samples. It indicated that levels of hydration did not affect the amylose content of rice samples. Cruz and Khush (2000) have shown that rice are grouped based on their amylose contents into waxy (0 to 2% amylose content), very low (3 to 9%), intermediate (20 to 25%) and high (>25%). The results of this study showed that the amylose contents of the samples ranged from 11 to 14% indicative of intermediate/low amylose content. This results are in agreement with earlier reports of Danbaba et al. (2011)

Table 5. Pasting characteristic of Ofada samples.

Samples	Parameters						
	PV (RVU)	TR (RVU)	BD (RVU)	FV (RVU)	SB (RVU)	PT (min)	PTemp (°C)
A	45.13 ± 0.13[a]	30.67 ± 0.25[a]	14.46 ± 0.38[a]	103.96 ± 1.29[a]	73.29 ± 1.54[a]	7.00 ± 0.00[a]	62.23 ± 0.43[a]
B	15.88 ± 1.17[b]	9.59 ± 1.17[b]	6.29 ± 0.54[b]	32.38 ± 1.96[b]	22.79 ± 0.79[b]	6.97 ± 0.04[b]	61.95 ± 0.00[b]

Key:
A = Sample soaked for eight days without changing the water.
B = Samples soaked overnight in hot water.
PV = Peak Viscosity; TR = Trough; BD = Break down Viscosity; FV = Final Viscosity; SB = Setback Viscosity; PT= Peak Time; PTime = Pasting Temperature.

Table 6. Mineral composition of samples processed by the prolonged soaking and improved methods.

Samples	Magnesium (g/100 g)	Sodium (g/100 g)	Potassium (g/100 g)	Zinc (g/100 g)
A	16.00 ± 0.01[b]	7.00 ± 0.00[a]	7.00 ± 0.00[a]	7.00 ± 0.00[a]
B	12.00 ± 0.0[c]	4.00 ± 0.00[c]	8.00 ± 0.00[a]	6.32 ± 0.32[a]
C	19.00 ± 0.00[a]	4.00 ± 0.00[c]	7.00 ± 0.00[c]	6.63 ± 0.15[a]
D	19.00 ± 0.00[a]	6.00 ± 0.00[b]	4.00 ± 0.00[c]	6.44 ± 0.19[a]

A = FARO 42 soaked for eight days without changing the water (traditional Ofada rice processing).
B = Ofada rice soaked for eight days without changing the water (traditional Ofada rice processing).
C = Ofada rice soaked for eight days with changing of water every day
D = Ofada rice soaked overnight in hot water (improved processing method).

and Anuonye et al. (2007) who reported values that ranged from 19.77 to 24.13% placing Ofada rice in the intermediate amylose content rice category.

Pasting characteristics

The result of the pasting characteristics (Table 5) showed very low values for peak viscosity. Wani et al. (2012) explained that peak viscosity reflects water-binding capacity or the extent of swelling of starch granules, and often correlates with the final product quality since the swollen and collapsed starch granules affect the texture of products. Xiangli et al. (2015) reported that peak viscosities (PV) from various rice starches ranged from 200 to 364 RVU. These values were significantly higher than the values reported in the present work for both samples of prolonged soaking and those of improved processing method. The differences are connected to the parboiling of these samples before the pasting analysis.

The minimum temperature required for cooking the Ofada sample soaked overnight and the one soaked for eight days was 62°C. Xiangli et al. (2015) reported pasting temperatures that varied between 68.4 and 82.8°C for several rice cultivars in China. The difference may be explained in line with the report of Sang et al. (2008) that amylose inhibits swelling of starch granules by forming complexes with lipids, which results in a lower peak viscosity at higher pasting temperatures.

Breakdown viscosity (BD) measured the starch paste resistance to heat and shear, while setback viscosity (SB) exhibited the tendency of starch pastes to retrograde, which is an index of starch retrogradation. High values in BD and low values in SB are indicative of high cooking quality since neither the cooked rice retrogrades nor becomes stiff upon cooling (Asante et al., 2013). The results of the present study showed that prolonged soaking led to high values of BD and SB indicating that the final product quality may be affected.

Mineral composition

The results of the mineral composition of soaked and unsoaked rice samples are presented in Table 6. The results showed significant ($P \leq 0.05$) differences between the samples. FARO 42 had higher mineral content than the Ofada samples. The Ofada samples soaked for eight days without changing the soak water had lower values in all elements analysed. This was consistent with the results of the proximate composition (Table 1) which showed that the ash content of samples soaked overnight was significantly ($P \leq 0.05$) lower than those of the prolonged soaked samples. The lower levels of mineral in the samples soaked for eight days are directly connected to nutrient leaching into the soak water. The results showed that the rest of the samples would be good sources of minerals which meet the recommended

Table 7. Acceptability profile of the processed samples compared to commercial samples.

Samples	Parameters evaluated				
	Appearance	Aroma	Taste	Floppiness	Overall acceptability
A	8.50 ± 0.75[a]	7.66 ± 1.26[a]	7.78 ± 1.34[a]	7.53 ± 1.68[a]	7.66 ± 1.68[a]
B	4.59 ± 2.00[b]	5.41 ± 2.27[ab]	5.50 ± 2.20[b]	4.78 ± 2.44[b]	5.75 ± 2.44[ab]
C	6.22 ± 1.84[b]	5.91 ± 1.65[ab]	5.63 ± 1.96[b]	6.69 ± 1.67[b]	6.16 ± 1.67[ab]
D	6.53 ± 2.12[b]	4.84 ± 2.29[b]	4.66 ± 2.29[b]	4.78 ± 2.54[b]	5.56 ± 2.54[b]
E	4.48 ± 1.65[b]	5.22 ± 1.96[b]	5.38 ± 1.96[b]	5.69 ± 2.36[ab]	5.75 ± 2.36[ab]
F	8.50 ± 0.75[a]	7.66 ± 1.26[a]	7.78 ± 1.34[a]	7.53 ± 1.68[a]	7.66 ± 1.68[a]

A = FARO 42 soaked for eight days without changing the water (traditional Ofada rice processing).
B = Ofada rice soaked for eight days without changing the water (traditional Ofada rice processing).
C = Ofada rice soaked for eight days with changing of water every day.
D = Ofada rice soaked overnight in hot water (improved processing method).
E = Ofada soaked overnight.
F = Ofada rice soaked for eight days with daily change of soak water.

dietary allowance according to Heinemann et al. (2005).

Sensory qualities

The results of the sensory properties of cooked samples compared to imported rice sample are presented in Table 7. The foreign rice sample had significantly higher scores than the other samples in appearance and taste. This was expected because most Nigerians prefer foreign rice to the local rice varieties. The results were in agreement with the values earlier reported for Ofada acceptability by Ebuehi and Oyewole (2007). The results did not indicate any significant (P ≥ 05) difference between the samples soaked for eight days and those soaked overnight in all the parameters measured. Equally, there were no significant variations in the values recorded for the commercial Ofada samples and the laboratory samples in most parameters evaluated. The sensory evaluation results indicated that the improved processing method did not produce more organoleptically acceptable Ofada rice probably due to bias of those who were used to the Ofada taste perception. It also showed that the traditional Ofada rice taste was not a generic phenomenon since it was not present in the sample soaked overnight in hot water but mainly due to the prolonged soaking process probably due to bacterial fermentation activities.

CONCLUSIONS

The results of this work showed that soaking Ofada rice for eight days without changing the soak water had significant influences on the functionality of the milled rice. The milling returns, the cooking characteristics, the pasting properties, etc were lowered. However the improved method of processing did not yield more acceptable milled Ofada rice. The sample soaked overnight in hot water did not carry the perceived generic Ofada taste. It is therefore concluded that Ofada rice taste and aroma is a function of the long soaking period and may not be generic after all.

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