

Towards improved rice processing in West Africa – the southwest Nigerian experience

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REVIEW ARTICLE

Abstract

West Africa currently imports over 5.2 million tonnes of rice, which only accounts for about 60% of its needs, despite considerable rice-growing potentials. The main impediments to local competitiveness and increased productivity are processing and marketing costs, coupled with poor post-harvest technology and/or systems. This article attempts to review the existing rice processing in southwest Nigeria as a barometer for reporting the rice processing challenges in West Africa. Also, the end-use characterisation of some improved Nigerian rice varieties are presented. Most of the existing production, harvesting and processing methods employed in Nigeria are traditional; hence the low paddy yield, prevalence of high levels of contaminants, broken grains and off-flavour in locally processed rice. Therefore, for Nigeria and other West African countries to be able to realise the government objectives of self-sufficiency in rice production and processing; there should be pragmatic policies and investment in mechanised rice production and modern rice processing equipment/technologies.

Keywords: rice processing, self-sufficiency, utilisation, research and prospects

1. Introduction

Rice (*Oryza sativa*) is a cereal belonging to the Poaceae family which is a large monocotyledonous grass plant family comprising about 600 genera and 10,000 species (Abulude, 2004). It is cultivated in over 100 countries, most of which are developing countries (FAO, 2008). Rice (paddy and processed) grain production serves as source of income and employment for over 100 million households in Asia and Africa (FAO, 2008). In many developing countries, rice is one of the main dietary sources of macro- and micronutrients, such as carbohydrate, calcium and zinc (Lieng *et al.*, 2008). Nigeria is the leading producer of rice in the West African region. In recent decades, Nigerian rice yield and productivity rose gradually, expanding the cultivated area, to surpass other major rice producing countries in West Africa (like Cote d'Ivoire and Sierra Leone). Ebuehi and Oyewole (2007) reported that the main factors driving increased rice production in Nigeria include population growth and urbanisation. Rice consumption in Nigeria surpassed its production as a result of the increase in the human population. In 2002, Nigeria accounted for about 57% of the total rice producing area in West Africa

(FAO, 2008). The annual demand for rice in Nigeria is estimated to be 5 million tonnes, whereas 3 million tons of milled rice is currently produced, resulting in a deficit of about 2 million tonnes. In the past years the country resorted to imports of processed rice to compensate for this deficit. According to FAO data, Nigeria imported 5,132,616 tonnes of rice valued at US\$1,883,553 million between 1990 and 2002. In 2002 alone, 1.882 million tonnes of rice was imported (FAO, 2008). Rice production in Nigeria between 2001 and 2003 was estimated as 2.03 million tonnes while consumption was 3.96 million tonnes; hence, the remaining 1.93 million tonnes had to be imported (FAO, 2008).

The prevailing economic situation in many West African countries with the attendant shortage of foreign exchange has made it necessary to examine the possibility of replacing imported food products with improved ones. Thus, in many West African countries there has been an increase in government interventions and initiatives with a focus on breeding and planting of rice (WARDA, 2006). Despite the awareness of improved varieties and increased production of rice all over the world, Nigeria is still a chief importer of rice. This is also due to a strong consumer preference

for imported compared to locally produced rice (Itabiyi, 2012). One of the reasons is that imported rice has a more attractive flavour and lacks impurities (Ebuehi and Oyewole, 2007; Itabiyi, 2012). In Nigeria, most of the rice harvesting and processing methods in use are still traditional, which results in high levels of impurities, broken grains and off-flavour in locally produced rice (Itabiyi *et al.*, 2016). Itabiyi *et al.* (2016) identified the major constraint to local rice acceptability to be the lack of consistent supply of good quality paddy grain for processing, since rice grains available in markets are often variable in kernel size, colour and cleanliness. Therefore, for locally produced rice to be able to adequately compete with imported rice, it requires more efficient methods of threshing and cleaning to free the grains from other impurities (Simonyan *et al.*, 2007). This review attempts to document the trends in rice processing and utilisation in southwest Nigeria. A couple of research efforts on the utilisation of improved rice varieties are also presented.

2. Rice processing in southwest Nigeria

This section briefly reviews the prevalent rice processing technologies in southwest Nigeria. The analysis is somewhat limited because of the dearth of published data as well as poorly coordinated national statistics on agro-processing. This underscores the need for a comprehensive study of rice processing systems in Nigeria as to provide information that will guide an appropriate policy action plan on the efficiency or comparative advantage of each rice production system.

Existing unit operations and technologies in rice processing

Rice processing in southwest Nigeria has witnessed a fairly basic processing technology in the aspects of parboiling and milling. Some of the challenges faced are a lack of access to improved technologies, high costs of energy for parboiling, lower output quality (post-processing), and limited government incentives, among others. After harvest, the rice is sundried (Figure 1) for some few hours after which the pedicles carrying the paddy are spread in barns. The rice is kept in this form until the farmer and/or processor are ready to process it further for the market.

Parboiling

The common practice is to parboil the paddy rice before delivery to the mills for milling. When there is a mill nearby, farmers may parboil their own rice, and then transport it to the mill for milling. The milled parboiled rice is then sold by the farmer in the local market or returned home for private consumption. If sold as paddy rice, the parboiling is done by the trader's family or given on contract.

Before parboiling the paddy rice is first loosened from the pedicles and soaked in water for 7-10 days depending on local preferences and how white/clean the farmer wants the final milled rice to be. The grains are then drained and transferred into large metallic pots covered with jute bags (Figure 2) and heated until the grains show signs of splitting, whereupon the rice is removed for drying. The problem with this process is the long soaking time which lead to commencement of fermentation. After parboiling, the paddy rice is removed from the water and sundried between 3 and 5 hours depending on the intensity of the sun. The parboiled paddy rice should not be over-dried to prevent breaking of the grain during milling, resulting in a higher amount of broken grains compared with head rice.



Figure 1. Sun-drying of paddy rice at village level.



Figure 2. Rice parboiling process in southwest Nigeria.

The average moisture content of the paddy after drying for optimum head rice yield is 16-25%. Previous studies have shown that head yield of short- and medium-grain cultivars usually decreases as the grain moisture content at harvest declines (Adeyeye *et al.*, 2013; Siebenmorgan *et al.*, 2007). However, the relationship between grain moisture content and head rice yield is also influenced by cultivar and environmental variations (Adeyeye *et al.*, 2013; Itabiyi *et al.*, 2016).

Drying

There is a lack of modern technology for drying the parboiled paddy rice in southwest Nigeria. Often, the parboiled paddy rice is dried on the roadside under the sun; commonly on the bare floor or spread thinly on a black polyethylene sheet. This practice allows the contamination of the dried paddy rice with foreign bodies such as stones, sand, leaf stalks and even animal excreta. Also, the possibilities for sun drying in the open are very limited during the rainy seasons. Consequently, this accounts for the low level of milling during these periods. When it is practicable to dry during the rainy season, the paddy rice often does not dry properly, resulting in the occurrence of foul odour in the final product. Many elite consumers cite this foul odour as the main reason for not patronising the locally processed rice.

Milling

Three methods of rice milling process/technology can be identified in southwest Nigeria. These are the traditional or hand pounding with pestle and mortar, the small hammer mill processing system and the large mill processing system (which has very limited availability as no more than 3-4

mills are present country-wide). The traditional hand pounding system is still being used by many village rice farmers in Nigeria. This process involves soaking of paddy rice for 24 hours followed by boiling in water for about 20 minutes. The boiled paddy rice is then spread in the sun to dry. After drying, the paddy rice is pounded in a mortar to separate husks and bran from the grains. After pounding the milled grains are winnowed to separate the bran. A drawback of the traditional process is that it is very slow and labour intensive. Furthermore, the final product obtained usually contains a high percentage of broken grains and foreign bodies/contaminants. As a result of these limitations, this process is being replaced more by the village level hammer mill station.

The small rice mills are the most predominant of the three rice-processing methods and they are found in major rice processing areas of Nigeria as well as other West African countries. Many different types of small millers exist; those who mill primarily as a service and those who purchase paddy rice and then mill for their own account (either for sale or home consumption). Personal discussions with rice experts showed that about 85% of paddy rice obtainable in southwest Nigeria is milled at the small milling stations. The Engleberg-type steel roller and cage huller are the most commonly used for milling the parboiled paddy rice (Figure 3). Most of the time, despite the precautions farmers and processors take during parboiling and sun drying, a lot of paddy breakages occur during milling. Most of the milling machines are diesel powered and only a few use electrical power. The use of diesel-powered engines by the majority of millers is due to the uncertain power supply in the country.



Figure 3. A typical rice mill in southwest Nigeria.

At the moment, the majority of the small rice mills operate at about 1 tonne/h capacity. The final product of the small mills is generally superior to that processed under the traditional hand-pounding process. However, in some milling units, the milled rice often contains a high proportion of broken grains which attracts a lower price in the market compared to head grains.

There exists huge economic prospects for the local rice milling sector if there is an inclination to invest in better processing technologies. The returns are very attractive given the large price difference between clean imported rice and the lower quality local rice, hence, justifying investments into the latest technologies, especially on areas like destoning. However, the imported rice supply/marketing chain is well established in contrast to the local rice market structure, which typically comprises of many different factors across the production, processing and sales value chains. The domestic rice value chains need significant improvement to be able to encourage more risk taking by large investors in the industry. Otherwise, local processed rice market system would not be able to achieve the economies of scale required to meet the government objectives of self-sufficiency in rice production and processing.

3. Rice utilisation in southwest Nigeria

In many parts of the world, rice grain is mainly used as food. The main forms of consumption being as boiled or steamed and eaten with meat, fish and vegetables. Rice has also many other uses in food and non-food industries (Futakuchi *et al.*, 2013). Rice is the best cereal crop in term of calories per hectare and is consumed in diverse forms such as plain rice, noodles, breakfast cereal, puffed rice, cakes, snacks foods, fermented sweet rice, wine and vinegar (Itabiyi, 2012). Rice starch is used as a thickener in infant foods, desserts and sauces or can be accompanied with vegetables, beef, poultry and seafood. Rice as a convenience food is economically viable, delicious, nutritious, easy to prepare and bland enough to pair with other foods (Itabiyi, 2012). Also, rice is easy to store on shelves in cupboards and pantries.

Studies have revealed that rice bran or hull contains antioxidants and it has been reported that rice bran oil can lower both the total and the low-density lipoprotein cholesterol in non-human subjects (Most *et al.*, 2005). Some health problems, such as thiamin deficiency (known as beriberi), growth retardation, marasmus, and vitamin A deficiency can result from consumption of only white rice from which a portion of the protein and most of the fat, vitamins, and minerals have been removed during the milling process.

In southwestern Nigeria, rice is commonly consumed as a food, either boiled or steamed and eaten with beef, chicken,

fish and/or vegetables. Sometimes it is ground into powder and then cooked into a doughy consistency and eaten with different types of soups. Some common rice recipes in southwest Nigeria and their preparation can be found on the internet (All Nigerian Recipes, 2014).

4. End use characterisation of improved Nigerian rice varieties

In conventional brewing processes, the primary raw material is barley because of its outstanding malting qualities. However, barley is not locally produced in Nigeria as in other tropical West Africa countries. The high cost of importing barley into Nigeria led to the adaptation of locally available cereals, such as rice, maize and sorghum as substitutes for barley in malting and brewing (Berry, 1991). Three tropical cereals have been recommended for use in the Nigerian brewing industry: sorghum, maize and rice (Adewoyin, 1985). Among these three, sorghum has mostly been studied as a replacement for barley and is presently widely used for malting and brewing in Nigeria (Aisien, 1988).

Adebowale *et al.* (2010) studied the malting characteristics of *Ofada* rice (a local Nigerian rice variety) and determined the chemical and sensory qualities. Malting parameters investigated were germinating energy, germinating capacity, malting loss, malting yield, and cold water extract. Rice malt was found to be acceptable with slight differences compared to commercial malt (Vitamalt™) by sensory panelists. Based on the outcome of this study, *Ofada* rice was recommended as an alternative in malting and brewing.

The economic situation with its shortage of foreign exchange has made it necessary for the Nigerian government to initiate national policies aimed at enhancing local rice production and processing. Strategies adopted include (but are not limited to) breeding and cultivation of high yielding, early maturing and nutritious rice varieties. This has resulted in an increase in local rice production and yield (FAO, 2008). However, for the country to be able to reap the maximum benefits from breeding and agronomical improvement strategies, there is a need for development of efficient processing equipment and techniques to add value to local paddy rice. This underscores the study of the engineering properties of the common and improved paddy rice varieties in Nigeria. Engineering properties have been reported to have great influence on the behaviour of agricultural commodities when subjected to various post-harvest handling and processing (Simonyan *et al.*, 2007). A study conducted by Adebowale *et al.* (2011) determined the effect of variety and initial moisture content on engineering properties of some improved rice varieties in Nigeria. It showed that the engineering properties of the improved paddy rice varieties was significantly affected by variety and moisture content (Table 1).

The combination of rice-bambara nut flour in the production of snack food was studied by Adebowale *et al.* (2014). The combination not only enhanced the nutritional quality of these snacks, especially through improved protein quality and quantity, but also served as a viable means of enhancing the commercial and industrial utilisation of bambara groundnuts. Adebowale *et al.* (2014) demonstrated the possibility of producing extruded flakes from rice and bambara ground nut composite flour using a single screw cooking extruder. The inclusion of bambara groundnut flour into rice improved the protein content of the flakes. Moreover, the rice-bambara flakes obtained from 90% rice and 10% bambara nut flour were mostly preferred by sensory panelists.

The New Rice for Africa (NERICA) is a research and development effort of the West Africa Rice Development Agency (WARDA). NERICA is an upland rice variety that is perfectly adapted to the rain-fed upland ecology in Sub-Saharan Africa, where smallholder farmers lack the means for irrigation or application of chemical fertilisers and pesticides (WARDA, 2006). Rice ratooning is the practice of harvesting grain from tillers originating from the stubble of a previously harvested crop. This method allows the

apical buds on the stubble to develop into full-grown plants, which would later flower and produce seeds for another harvest (Adigbo *et al.*, 2012). There are many advantages of this method including that there is no need to burn the paddy fields, re-till the soil or buy new rice seeds. The method also reduces the amount of water needed and other production inputs. Ratooning has been found to enhance rice grain yield without increasing land area because it provides better resource use efficiency per unit land area per unit time (Bond *et al.*, 2005). Itabiyi (2012) characterised the physical, chemical, thermal and culinary properties of main and ratooned lowland NERICA rice grains grown in southwest Nigeria. The author showed that the physical, chemical, thermal and culinary properties varied significantly ($P<0.05$) between the different NERICA varieties and the ratooned grains. The NERICA varieties were found to be longer in length, thinner than and not as wide as the *Ofada* rice variety. The linear dimensions of the NERICA paddy were found to be higher than those of some other rice varieties (like *Poya*, *Khazar* and *Haraz*) earlier reported by Farahmandfar *et al.* (2009). However, the study showed that ratooning does not constitute a significant factor in determining the linear dimensions of the lowland NERICA varieties (Table 2).

Table 1. The effect of variety and moisture content on some engineering properties of improved paddy rice varieties (Adebowale *et al.*, 2011).

Variety	Moisture content (%)	Apparent volume (cm ³)	True volume (cm ³)	True density (g/cm ³)	Bulk density (g/cm ³)	Porosity (%)	Aspect ratio (%)
FARO55	10	13.8	3	0.95	0.61	37.8	26.1
	20	16.7	3.2	1	0.57	46.1	30
	30	17.3	3.6	1	0.54	46.1	28
FARO44	10	14.2	2.7	1	0.6	40.9	24
	20	15.1	2.9	1	0.58	41.8	25.7
	30	15.4	3.3	0.97	0.54	44.5	25.3
FARO52	10	14.0	2.6	0.89	0.61	32.6	26.2
	20	15.3	2.7	0.98	0.57	41.5	26
	30	14.5	3	0.94	0.55	41.2	24.9
NERICA L34	10	13.0	2.3	1.1	0.62	43.5	23.7
	20	14.5	2.8	1	0.58	42.1	24.1
	30	14.9	3.2	0.99	0.51	47.5	24.2
FARO49	10	17.8	3.1	1	0.58	42.1	32.6
	20	20.5	3.6	0.94	0.59	42.8	32.3
	30	21.2	3.9	0.97	0.55	42.9	32.5
Mean		15.9	3.1	0.99	0.57	41.8	27.1
Standard deviation		2.4	0.43	0.05	0.03	3.85	3.37
Standard error		0.62	0.11	0.01	0.01	0.99	0.87
Coefficient of variation		15.13	14.12	4.82	5.28	9.19	12.42
<i>P</i> -value of variety ¹		**	**	**	ns	**	**
<i>P</i> -value of initial moisture content ¹		**	**	**	**	**	**
<i>P</i> -value of variety × initial moisture content ¹		**	**	**	ns	**	**

¹ ** significant at $P<0.05$; ns not significant, $P>0.05$.

Table 2. Linear dimensions of lowland NERICA rice varieties grown in Nigeria (Itabiya, 2012).¹

Variety ²	Length (mm)	Width (mm)	Thickness (mm)	Arithmetic mean diameter (mm)	Geometric mean diameter (mm)	Equivalent diameter (mm)	Aspect ratio (%)	Surface area (mm ²)	Sphericity
NL 19	10.62 ^k	2.70 ^{efg}	2.19 ^h	20.43 ^h	3.87 ⁱ	9.13 ^h	25.43 ^{bc}	47.33 ^h	0.37 ^{cd}
NL 20	10.54 ^k	2.68 ^{efg}	2.21 ^{hi}	20.27 ^h	3.86 ^{hi}	9.10 ^h	25.42 ^{bc}	47.39 ^{gh}	0.37 ^{cde}
NL 41	9.51 ^{fg}	2.81 ⁱ	2.03 ^{ef}	17.47 ^{cde}	3.68 ^{def}	8.10 ^{cde}	29.63 ^{hi}	43.20 ^{cde}	0.39 ^{ij}
NL 22	9.89 ^{ji}	2.71 ^{fgh}	2.10 ^g	18.23 ^{def}	3.72 ^{efg}	8.36 ^{ef}	27.43 ^{ef}	44.40 ^{def}	0.38 ^{gh}
NL 24	9.61 ^{gh}	2.91 ^j	2.11 ^g	19.17 ^{fg}	3.79 ^{gh}	8.70 ^{fg}	30.34 ⁱ	45.87 ^{fg}	0.40 ^j
NL 26	9.32 ^{def}	2.63 ^{def}	1.98 ^{de}	15.70 ^b	3.56 ^c	7.45 ^b	28.29 ^{fg}	40.23 ^b	0.39 ^{hi}
NL 42	10.04 ⁱ	2.76 ^{hi}	2.20 ^h	19.87 ^{gh}	3.82 ^{hi}	8.95 ^h	27.56 ^{ef}	46.83 ^{gh}	0.39 ^{hi}
NL 44	10.38 ^k	2.81 ⁱ	2.18 ^h	20.63 ^h	3.66 ^{de}	9.26 ^h	27.20 ^{ef}	48.13 ^h	0.38 ^{efgh}
NL 47	9.95 ^{ji}	2.57 ^{cd}	2.08 ^{fg}	17.23 ^{cd}	3.87 ⁱ	7.98 ^{cd}	25.80 ^{cd}	42.77 ^{cd}	0.37 ^{cdef}
Ofada	8.21 ^a	3.35 ^k	2.28 ⁱ	20.47 ^h	3.52 ^{bc}	9.13 ^h	40.99 ^j	47.70 ^h	0.48 ^k
Variety ³	**	**	**	**	**	**	**	**	***
Ratooning ³	**	**	**	**	**	**	**	**	**
Variety × Ratooning ³	**	**	**	**	**	**	**	**	**

¹ Means (n=30) followed by different superscript within the same column are significantly different (P<0.05).

² NL = NERICA Lowland.

³ ** significant at P<0.05; *** significant at P<0.01.

Itabiya *et al.* (2016) reported on the engineering properties of different varieties of main and ratooned lowland NERICA paddy grains. The engineering properties of the main rice crop were significantly different from the ratooned crops. However, existing equipment used for handling and processing conventional rice varieties could be suitable for the NERICA rice varieties (main or ratooned) with slight or no modification, because some of the engineering properties of the NERICA were found to be similar to existing conventional rice varieties (Adebowale *et al.*, 2011; Itabiya *et al.*, 2016).

Adeyeye *et al.* (2013) reported on the milling characteristics of parboiled improved Nigeria rice varieties. The author concluded that parboiling process enhanced the yield of head rice and that the parboiling process also had potential to concentrate some nutrients, especially proteins.

5. Prospects for research and development

Many opportunities exist in the Nigerian rice processing industry. The country should not miss these huge economic opportunities (social and economic) in rice production because the potential is there. Nigeria has the capacity to provide the required farm inputs that can conveniently transform rice productivity in the near future. Research efforts and breakthroughs, as well as farmers' enthusiasm should not be dampened by misguided food importation policies. Most importantly, the nation needs the political will and support of Asian countries like India, Malaysia,

Thailand, Pakistan, Cambodia, Indonesia and the Philippines to tackle issues of food insecurity, especially through adequate funding of agricultural research systems. Nigeria has the potential capacity to join the league of rice exporting countries if adequate research and political attention is given to production and processing of NERICA varieties. NERICA and other improved African rice varieties have been given recognition in research centres because their resistance to major rice diseases and pests in Africa. For example, the 'Ofada' variety that is currently used in fast food centres can take the country there if rightly handled and packaged to world class standards. Part of the agenda of the present Nigerian government is to stop the import of processed rice in the next three years. At the moment Nigeria imports a lot of processed rice, which drains the economy as much of the foreign exchange is spend on it.

This review has attempted to raise a number of research and policy issues. Indeed, numerous research gaps have been identified which require further research. Some of the research questions are:

Regarding processing:

- What kind of rice processing technologies/systems is in use?
- What is the profitability of utilisation of these technologies/systems?
- What is the potential to mechanise and/or upgrade the existing processing technologies/systems?

- What are the factors that hinder the adoption of modern rice production and processing technologies?
- Does sufficient reward or incentives exist for conformance with international quality?

Regarding consumption:

- What is the share of rice expenditure in total household consumption expenditure?
- What is the level of rice consumption at household and national levels?
- What are the levels of rice preference for Nigerians – imported or local and, what factors are responsible for this?

Progress towards regional self-sufficiency in rice production and processing can be made through the introduction of integrated value chains in which industrial rice mills will maintain formal links with upstream and downstream value chain actors. Public-private partnerships also offer genuine scope for development in West African countries with substantial rice-growing potential, such as Nigeria, Mali, Ghana, Republic of Benin, and Senegal. The emergence of an integrated local rice production sector also offers an opportunity to professionalise the rice sub-sector and could in turn, boost the purchase of locally processed rice. However, it could be misleading to assume that such partnerships or collaborations would avoid resorting to rice imports from the international market in the short- and medium-term.

6. Conclusions

The majority of rice consumers in West Africa still have a preference for imported processed rice over the locally produced rice. The quality of locally produced rice needs much improvement to ensure consistent quality grains that are free of contaminants especially sand and stones. Most of the existing production, harvesting and processing methods employed in Nigeria are traditional; hence the low paddy yield, prevalence of high levels of contaminants, broken grains and off-flavour in locally processed rice. Therefore, for Nigeria and other West African countries to be able to realise the government objectives of self-sufficiency in rice production and processing, there should be pragmatic policies and investment in mechanised rice production and modern rice processing equipment/technologies.

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