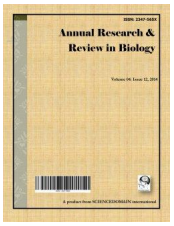

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Ofada Rice Identity, Physical Qualities and Processing Technology Options for Upgrading: A Review

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Authors' contributions

This work was carried out in collaboration between all authors. Author OOA was principally involved in the design of the protocol, literature searching and wrote the first draft. Authors SAF and ARI contributed in further literature search, correction and moderation. All authors read and approved the final manuscript.

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ABSTRACT

The main aim is to provide an overview on identity of Ofada rice and technology options for quality upgrading. Ofada rice is one of the popular indigenous Nigerian rice with complicated identity. This local rice is robust with red/brown stripes and characterised with unappealing appearance causing downgrading or rejection. Physical qualities play a significant role in the determination of consumer preference. Aside from genetic, non genetic factors contribute substantially to the physical quality of rice. The quality differences between Nigerian rice and imported rice varieties have been of concern to the domestic rice industry. Careful examination of research findings have lent strength to the influence of post harvest rough rice handling and processing on the quality of Ofada rice. Most of these previous researches to improve *Ofada* rice quality focused on a particular processing unit operation (soaking condition and time, parboiling temperature, drying temperature and storage

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duration). Identity of Ofada rice and its physical attributes are re-examined. The traditional primary and secondary processing operations involved are also revisited. Appropriate technological options for improving physical qualities for better product quality and acceptability were compounded.

Keywords: Ofada rice; identity; upgrading; physical qualities; processing conditions.

1. INTRODUCTION

The growing demand for imported rice and high import demand have spurred interest in the development of domestic rice varieties. Nigeria is the highest importer of rice in Africa, and the second highest in the World [1]. Rice imports in Nigeria have represented a good proportion of total food imports overtime [2,3], and there exists a threat to the Nigerian economy due to large volume of milled rice imports into Nigeria, with an import bill currently exceeding US$2 billion [4]. The quality differences between Nigerian rice and imported rice varieties have been of concern to the domestic rice industry for over a decade.

The non competitiveness of Nigerian rice industry is majorly as a result of obsolete and inefficient processing technology (especially parboiling) which lead to smelling and unappealing products, presence of stones, and uneven grains [5,6]. The market demand and values of rice depend on its physical qualities such as head rice yield, chalkiness, brokenness, colour, size characteristics and so on which is subject to processing conditions of paddy [7]. Although, genetic factors play a large role in the determination of rice grain attributes, non-genetic factors contribute substantially to the physical, chemical, and sensory attributes.

Local rice cultivation is widespread within the country extending from the northern to southern zones. There are two cultivated species of rice, the *Oryza glaberrima Steud* and the *Oryza sativa* L. Oryza glaberrima was first cultivated in Africa popularly known as wild rice. However, with the introduction of *O. sativa*, the indigenous rice species *O. glaberrima Steud* was pushed to the marginal areas. Notable parts of Nigeria known for rice cultivation are: Abakaliki, Bida, Abeokuta, Markudi, Mokwa, Sokoto, Ekiti, Obubra, Nasarawa, Taraba, and Benue [8,9]. Some grown species of rice have over time derived their names after the towns in which they are grown, such name as Abakaliki rice which denotes all varieties of rice from Abakaliki area [5]. Ofada is one of the popular local rice in Nigeria due to its unique taste and aroma. The identity of real Ofada rice is complicated as it is becoming difficult for consumers to identify in the market. There exist large variations of Ofada rice due to disparity or inefficient processing technology. Therefore, this review examined the true identity of Ofada rice and physical attributes. The traditional processing technology was also revisited and technological options adapted at upgrading its physical quality are suggested.

2. IDENTITY OF OFADA RICE

Ofada is a generic name used to describe all rice produced and processed in the rice producing clusters of the South-West Nigeria [10,11,12]. Due to its unique taste and aroma, it is more popular than other local varieties. It was believed to have been introduced by veterans returning from the First World War The first area of introduction was Ofada, a small rural community in Obafemi Owode Local Government area of Ogun State [12]. [13] affirmed that the first area of Asian rice cultivation was Abeokuta, Ogun State and introduced through missionary activities in 1850s; to 1970s when it spread to Lagos area in Epe and Okitipupa; from there it moved to Ogoja and Abakaliki provinces after the Second World War. It then spread across the sahara and to northern Nigeria via the oases and the Trans-Saharan trade [13]. The reports revealed that the first place of cultivation was in Egba zone, Ogun State, Nigeria. Western part of Nigeria played an important role in the introduction of Asian rice in Nigeria. *Ofada* rice is upland rice grown on free-draining soils where the water table is permanently below the roots of the rice plant.

The original *Ofada* rice is short grain, robust rice with brown stripes believed to be OS6 and ITA 150 varieties [14,12]. *Ofada* rice could be likened to the popular “basmatic rice” from India and Pakistan. It is unpolished short grain with red kernels which researchers say is not related to any other rice known in Nigeria. The earliest released variety of Ofada rice was the upland variety FARO 3 popularly called “Agbede”, followed by *OS 6* which was released as FARO 11. Other varieties emanated through breeding effort at improving the variety available for specific purposes. Additional varieties such as

ITA 150 and NERICA 1 were released as FARO 46 and FARO 55 respectively [12]. Presently, NERICA II (N2R) has been released and cultivated in South West, Nigeria [15]. NERICA (New Rice for Africa) is a progeny which exhibits hybrid vigour with the advantages of both *O. glaberrima* and *O. sativa* surpassing both in many regards [16].

Different combinations of rice in breeding programmes produced various rice varieties released as Ofada rice. In 2011, Federal University Abeokuta (FUNAAB), released two purpose Ofada rice varieties (Funaabor-1 and Funaabor-2) which were selected through bottom-top seed collection approach from farmers field in part of Ogun State [17]. Funaabor-1 is brown while Funaabor-2 is white with characteristic attributes for qualities. According to [18], IRAT 170, a cross of IRAT 13 and Palawan was introduced from the Ivory Coast with a better cooking quality (amylose 23.0 %) better than FARO 11(amylose 19.0%). In 1977, varieties such as E-425, OS4, FARO 25, IRAT 1069m-1-2 and IRI 154-243-1 were released based on agronomic characteristics. FARO x299 was a cross breed involving IRAT 1069m-1-2 with other varieties FAROX 298, FAROX 300, FAROX 301, FAROX 302 [18].

Certain varieties are related in physical, chemical and morphological characteristics. Genetic plays a large role in the determination of rice grain attributes, such genetic variation from different breeds of Ofada rice released would have contributed to variation in attributes. Non genetic factors also contribute substantially to the physical, chemical, and sensory attributes. For example, Ofada 11 and 12 are related to WAB450-24, ITA 117 and ITA301 [12]. The processing unit operations involved in Ofada rice processing in the cluster areas where the rice is produced are related with few variations. This may also contribute to the general characteristics of Ofada rice [10].

Ofada rice is consumed mostly in form of boiled rice eaten with specially prepared sauce using pepper (atarodo), onion, locust beans, palm oil and assorted meat [14,19,20]. [20] reported production of ready-to-eat flakes from Ofada rice flour. The study presented by CMRG - a market research agency, and Emerging Market Economics Limited (EME) based in the U.K, showed that among cities and towns in the South West, Abeokuta in Ogun State recorded a significantly higher consumption level with 58%, followed by Ilesa in Osun State (38 %). Members of the trade and professional buyers also confirm the South-West as the dominant producing and consuming areas for *Ofada* rice [21].

3. PHYSICAL CHARACTERISTICS OF OFADA RICE

The physical quality of milled rice is characterized by a combination of desirable and measurable characteristics. In line with the market requirements, these are used to classify rice into grades which varies for different countries. Rice grades depend on the buyers' preferences. Size characteristics ((length, width, breadth), colour (whiteness), milling degrees, head rice, damaged grain, and chalkiness are the major physical characteristics that determine quality of rice [22,19]. Consumers judge the quality of rice on the basis of size, shape, appearance, and colour of grain. The non-competitiveness of Nigerian rice with imported rice is majorly as a result of poor physical quality.

According to [23], the type of milled rice is classified according to the length of the whole grain, thus;

a. Extra long - milled rice of which 80% of the whole milled rice kernels have a length of 7.0 mm. or more.
b. Long -milled rice of which 80% of the whole milled rice kernels have a length of 6.0 mm. or more but shorter than 7.0 mm.
c. Medium -milled rice of which 80 % of the whole milled rice kernels have a length of 5.0 mm. or more but shorter than 6.0 mm.
d. Short -milled rice of which 80 % of the whole milled rice kernels are shorter than 5.0 mm.

Ofada rice is believed to be short grain rice but the influence of certain processing conditions could reclassify it to medium or long grain rice [24]. Classification of length of Ofada rice as documented by some authors is provided in Table 1.

None of the authors has recorded Ofada rice as short rice grain based on FAO classification. The use of ‘short’ for the classification emanated from the estimation of rice shape which is length divided by the width (L/W). The variations in the classification might also be due to varietal differences [25]. Size, shape and width are parts of the top criteria to determine the quality of rice and breeders are also consistent to develop new

Table 1. Length characterisation of Ofada rice

Authors	Extra long	Long	Medium	Short
Adekoyeni et al., 2012		***	***	
Anuonye et al., 2016		***	***	
Danbaba et al., 2011	***	***	***	
Ebuechi and Oyewole (2007)		***		
Otegbayo et al., 2001	***	***		
ARC and NRCI, 2007		***	***	

Extra long rice grain: grain above 7 mm
Long rice grain: grain less than 7 mm but not below 6 mm
Medium grain: grain less than 6 mm but not below 5 mm
Short grain: grain less than 5 mm

varieties from this commercial point of view [26]. Table 2 revealed reports of some authors on width of Ofada rice. The range of the width grain recorded is between 2.04 – 3.05 mm. Prolong soaking condition and improve methods of processing such as parboiling temperature affect the width of rice [14,10]. In consumers' perspectives, the length to breadth ratio ranging from 2.5 to 3.0 is widely acceptable and the grain length > 6 mm is preferred. The size and shape of rice grain may vary from one group to another of different regions. According to [27] as reported by [28], parboiling and influence of amylose content contributes to the expansion ratio of rice as a result of increase in water absorption capacities of the rice varieties. *Ofada* rice is believed to be short grain rice but the influence of certain processing conditions could reclassify it to medium or long grain rice [24]. In contrary, [29] revealed that parboiled rice kernel has a short length and broader breadth when compared with the non-parboiled rice sample. [25] also claimed that processing method did not affect the size of rice but the varietal factors.

Table 2. Width of Ofada rice

Authors	Range(mm)
NCRI and ARC, 2007	2.8-3.2
Anuonye et al., 2016	2.03-2.59
Adekoyeni et al., 2012	2.82-3.05
Danbaba et al., 2011	2.6-3.2
Ebuechi and Oyewole (2007)	2.04

The milling characteristics such as head rice yield and brokenness are really subject to processing parameters [10,29]. [30] recorded breakage percentage range of 18.6 – 26.1 % for FARO 15 and OS 6, [29] recorded 55 – 65 % breakage for parboiled Ofada rice. Non parboiled Ofada has large percentage of brokenness compared to parboiled rice. Parboiling is a hydrothermal process in which the crystalline form of starch present in paddy rice is changed into amorphous form and expands until it fills the surrounding airspaces, becoming a homogenous compact mass [31]. This process that produce compact and vitreous grain structure increase the milling yield. Other processing operations involve in rice processing such as soaking temperature and time, parboiling temperature, drying temperature affect head rice yield (HRY) and brokenness. [30] suggested drying of paddy under shade at 30°C. According to [32] the effect of parboiling temperature and cultivar were discovered as the reason behind the variation in HRY of rice. Well parboiled rice is harder and gives a higher yield of head rice upon milling and incomplete parboiling causes increased kernel breakage upon milling [32]. Broken grains produced during milling are generally the result of immature, low moisture, chalky, or fissured kernels all of which are weak and typically break during milling due to the substantial forces imparted to kernels in order to remove bran [33, 34]. The kernel of rice can become cracked in the field, during the dumping process, or during the milling process. Cracks are usually caused when moisture is migrating quickly within the kernel (chopping too fast, or moisture being added back to a dry kernel) [35]. Severe brokenness are only approximately 60 % of the value of head rice. HRY directly determines the economic value of rice [36].

Research has shown that rough rice storage history can affect head rice yield and cooking quality of rice [37,38,39]. Changes during storage include increase in grain hardness and these changes occur most rapidly in the first months of storage [35]. This showed that traditional practice of storing paddy on roof for certain period before processing increase head rice yield.

Chalky rice occurs when part of the grain is whiter than the rest because this is where the

starch has not developed properly and it is a point of weakness. Chalkiness disappears upon cooking and has no effect on taste or aroma. However; it downgrades the grain quality and reduces milling recovery [40]. Two things are known to cause chalkiness, the genetics of the rice variety and higher growing temperatures. Unfortunately, since farmers cannot manage their rice crops to reduce grain chalkiness nor can they do anything to change temperature; they must rely on growing varieties less susceptible to chalkiness. A lot of research is still on to find out why it has been so difficult to eliminate chalkiness from rice improvement programs [41]. Findings have shown that appropriate processing technology could reduce chalkiness in rice grain [10,42].

Colour is an important attribute in acceptability of food products such as rice. As described by [43], the products of Ofada rice in the market are recently classified into three due to mixtures presently in circulation among farmers:

Red Ofada- Brown in colour, with a very strong aroma which is believed to be the real Ofada rice. The appearance in uncooked form is unappealing; however, it is sweeter and smells better.

Straw colour Ofada rice- This is whitish in colour and more appealing. When cooked, the aroma is mild and the taste is not as distinct as the red/brown Ofada rice.

White Ofada- This is more attractive. The mode of cooking is the same with cooking normal Ofada rice. The aroma and taste were seen about the same as normal Ofada rice.

According to [17] two main breeds of Ofada rice were produced base on the colour of the hull. Ofada rice gold (Funaabor I and Ofada white (Funaabor 2).

The impact of low drying temperature is good for the processing of *Ofada* rice similar to the result of [30] which recommended the drying of rice in shade under good aeration. Increase in parboiling temperature reduced colour value. This is similar to the investigation of [44], that due to parboiling treatment, discolouration of grain occurs which decreases the lightness value. The negative effect of parboiling is as a result of discoloration of rice mainly caused by Maillard type non enzymatic browning and the processing conditions determine the intensity of colour during parboiling

4. PROCESSING TECHNOLOGY OPTIONS FOR IMPROVING PHYSICAL QUALITY OF OFADA RICE

Ofada rice is usually parboiled rice. Rice processing according to [45] consists of two inter-related phases: primary and secondary processes. The primary processing includes harvesting, threshing, cleaning and drying while the secondary process involves four stages of treatment; soaking, parboiling, drying and milling. The methods of process handling vary from one locality to the other which results to large variation of quality of *Ofada* rice available in the market. Processing of rice started from farm gate where rice is sorted according to variety. The rice paddy is separated from the stalk by the process known as threshing. This operation can be performed either manually or mechanically. The traditional method of threshing is achieved by human trending on the panicles or flailing the stalks by hand [30]. Pounding of rice stalks in bags is also practiced in some locality. This operation is followed by winnowing to remove the shafts and other foreign materials present.

Storage of Ofada rice paddy prior to processing requires good handling. Rough rice stored at high humidity content may develop greater percentage of discoloured kernels. [46] stated that yellow rice results from heating of stored unthreshed grain. This suggests traditional storage of paddy on the roof beneath corrugated roofing sheets may caused yellow rice due to high temperature. Therefore, rice should be stored in cool place to prevent heat. They also speculated that yellowing is caused by fungal respiration at very high humidity. Paddy is advised to be stored at moisture content below 20% [47]. However, non enzymatic browning and influence of temperature and water activity were also found predominant in rice yellowing [48].

Traditionally, parboiling involves soaking the paddy in cold or warm water with the duration of steeping varying from 4 to 5 days for cold steeping or overnight for warm steeping [45,10]. During soaking, water penetrates the endosperm of paddy and forms hydrates by hydrogen bonding. The grain swells which causes increase in the volume of the paddy. For the purpose of upgrading the quality of locally produce Ofada rice, [49] suggested that soaking should not be prolonged to avoid fermentation which affects colour, taste and odour of rice. [50] reported that soaking parameters like soaking time, degree of hotness and moisture content after soaking

influence translucency, colour and deformed grains. [51] suggested inoculation of certain microorganism during soaking to prevent growth of microorganisms which may induce bad characteristic flavour into the paddy during soaking. [30] suggested cold steeping in cold water with addition of 0.5% alum or steeping in warm water overnight or 5 – 6 h which is a common practice in Badeggi, Nigeria.

Steaming of paddy is carried out in metal drums or earth ware pots until splitting of the husks is observed which takes between 15 and 20 min. The surface area exposed to hydration is increased and the granules swell in an irreversible manner, a phenomenon known as gelatinization. The paddy is then drained and sundried on raffia mats or concrete floors. Drying is completed when grains selected at random give a sharp cracking sound on breaking with teeth. The old method of pounding the dried paddy in mortar and pestle device to remove the husk has been replaced with the use of Grantex dehuller after which the milled rice is packaged and ready for sale [52,30].

The major reasons for parboiling rice include higher milling yields, higher nutritional value and resistance to spoilage by insects and mould [53]. Variation in parboiling parameters is widely responsible for the quality variation of milled rice in the market. [42,54] Ibukun reported effect of parboiling temperature on the quality of rice. Pressure parboiler and warmer for soaking are commonly employed in modern rice processing technology. This provides adequate temperature monitoring for optimum production. Effect of varying the degree of parboiling temperature on quality of rice using a fabricated parboiler was recorded by [55]. The use of low steaming temperature was recommended to both household and commercial parboiling plants in the production of a good quality rice product. Parboiling temperature at 100 – 119°C for 15 min have been found favourable, this may also depend on the variety of Ofada rice. Recently, more sophisticated procedures such as dry-heat parboiling and pressure parboiling have been applied [56].

Drying is traditionally done under the sun. Sun drying involves spreading of the paddy on ground, road side on a raised platform in thin layers of 2 - 3 cm to expose it to solar radiation. This method is low cost but suffers from various drawbacks. It is labour intensive, entirely weather dependent and in rainy or damp weather, drying is unduly delayed causing spoilage, exposure of paddy to birds, rodents and contaminations with foreign materials, also drying is not uniform [57,58]. Mechanical drying is a better option which entails forcing heated air through the parboiled rice to evaporate and remove moisture [59]. The system consists of an air heating device (electrical heater, furnace or burner), a fan and drying chamber with appropriate air duct. The drying can be carried out in batches or continuous flow system. Mechanical dryer which uses electricity and diesel were reported by [60]. Solar dryer uses solar energy collector for heating the air and is been adopted as alternative to mechanical dryers. [61] recommended low drying temperature at about 30°C under shade for better rice quality.

The commonly use milling machines are Satake SB-2B and Sabriku mills. [62] designed a prototype milling machine with sieve shaker and has between 45-80% head rice mill rice depending on the input. Enzymatic polishing of rice using xylanase and cellulose produced from *Aspergillus sp*. and *Trichoderma sp*. was also investigated and found effective in rice polishing [63].

5. CONCLUSION

Ofada rice though is regarded as short grain based on its shape and not length. It is robust rice with red/brown stripes and aromatic with distinct taste when cooked. Reports showed that the grain could be medium and long grain in length depending on the variety and processing parameters. The rice was first introduced in Ogun State, Nigeria. Careful post harvest handling such as reduction of moisture of rough rice after harvest reduces yellowing of milled rice. Appropriate paddy pre-treatment and selection of processing parameters such soaking condition, parboiling temperature, drying temperature improve physical quality of Ofada rice.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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