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# Rice Postharvest Technology in Nigeria: An Overview of Current Status, Constraints and Potentials for Sustainable Development

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## Abstract

In 2016, the total estimated paddy production in Nigeria was 17.5 million metric tons (MMT) which is equivalent to 5.7 MMT milled rice. This is 1.3 MMT lower than the projected 7.0 MMT national consumption demands. This implies that Nigeria is progressing towards achieving self-sufficiency in rice if this data is compared with 3.5 MMT milled rice production in 2010. But about 10% - 30% or more of this increase does not reach the final consumers largely due to inefficient postharvest management practices. Huge postharvest grain loss (PHGL) and postharvest grain quality loss (PGQL) have been reported and significant efforts have been made towards reducing them and improving food security, but this is hampered by lack of simple, cost effective, adoptable and well-defined practical postharvest management practices and technologies. This situation has presented huge opportunity for investment and strategic interventions. From the point of harvest till rice reaches the consumers table, rice passes through wide range of unit operations which may have impact on the quantity and quality of the milled rice, these have made value chain actors adopt different practices to manage the process as it passes through the various unit operations. This paper examines the current rice post-harvest management technologies in Nigeria, with attention focusing on the current practices, constraints militating against the improvement of the rice postharvest system and opportunities it presents for improvement taking into account the main contribution of the research and development organizations in solving rice postharvest related challenges and lessons to be learned that will sharpen future direction for sustainable devel-

opment.


## Subject Areas

Agricultural Science, Food Science & Technology

## Keywords

Rice, Postharvest Loss, Constraints, Potentials, Research, Nigeria


## 1. Introduction

Demand for food especially rice in developing countries is expected to continue expanding for several years to come mainly due to population growths, rising per capita income, urbanization, changing weather conditions and occupational structure, consumer demands and taste, drop in the consumption of other native cereals such as sorghum, millet and maize. In developing countries including Nigeria, approximately 60% of total calories consumed are obtained directly from cereal grains [1]. Rice (*Oryza sativa* L.) is the most important among these cereal grains in term of calorie consumed [1] [2]. Even though the per capita consumption is declining in many parts of Asia, in sub Saharan Africa (SSA) for instance, the demand for rice is increasing and at a faster rate than in any part of the world [3].

In Nigeria, rice is currently the leading food crop and is cultivated in all the agro-ecological zones, from the Sahel of the far north, through the Savannah grass land of the north central to the mangrove and swampy ecologies of the south [4] [5]. It has been estimated that out of the total Nigerian land mass of 723,770 $Km^2$, 84 million ha are suitable for crop cultivation, and 40% representing 47.62 million ha are used for crop cultivation of which only 10% representing 21.0 million ha is used for rice production [6]. The vast land available for rice production suggests that Nigeria is one of the locations for global expansion of rice production because of the limited land available for further expansion in major rice growing areas of the world. Currently, Nigeria is the leading rice producer in Africa and is also the second highest importer of rice in the world.

Available statistics indicated that in 2016, an estimated 17.5 million tons of paddy was produced, with a market surplus of 11.4 million tons which is equivalent to 5.7 million tons of milled rice. This production is 1.3 million tons less than the 7.0 million tons estimated national consumption demand for milled rice. The deficit in production has a significant implication for food and nutrition security and foreign exchange [6]. Currently, an average Nigerian consumes about 34.0 to 47.0 kg rice/person/year. Even though this figure is lower than the global per capita consumption of milled rice estimated at 53 kg/person/year [7], the Food and Agricultural Organization (FAO) of the United Nations projected growth in rice consumption for Nigeria at 4.5% per annum [8] which implies that beyond 2018, the demand for milled rice will be above 7 million tons and the total volume of rice to be consumed in Nigeria is likely to increase by 70% to 80%.

In spite of these sizeable land and favorable agro-ecological conditions, the Food and Agriculture Organization [9] states that in 2012 about 6 per cent of the population were undernourished while poverty and unemployment levels in 2017 were also high estimated at 69 per cent [10]. Based on this statistics, the level of poverty, food insecurity and undernourishment in Nigeria coupled with food losses and waste, which occur along the entire food value chain is important to look back at what action needed to be taken and at what point to reduce losses and improve food and nutrition security. This therefore will require concerted efforts in increasing productivity through increase in crop yield, expansion of area under cultivation and reducing postharvest losses through good production practices and adoption of improved technologies. The government of Nigeria under different policy regimes and restriction strategies (National Accelerated Food Production Programme, 1972-1973; Operation Feed the Nation, 1976-1980; Green Revolution Programme, 1981-1983; Back to Land Programme, 1983-1985; Agricultural Transformation Agenda and The Green Alternative, 2016-2020) have been discouraging importation of rice, but support local production and processing [11] [12]. The current policies and programs are aimed at increasing domestic agricultural production are enshrined in the Agricultural Transformation Agenda Support Program-Phase 1 (ATASP-1) policy and aimed at self-sufficiency in rice and other staple crops production and complete cessation of importation [13]. This policies and programmes have significantly improved national production, but not much improvement has been observed in the postharvest component of the value-chain, especially among small and medium scale rice farmers.

The main objective of this paper therefore is to synthesis current status of rice postharvest management systems in Nigeria as they effect rice production and sustainable food security. It also aimed at identifying major constraints and possible opportunities in the rice postharvest value chain that can attract investment for sustainable rice production. The contributions of research and development to the improvement of the rice postharvest operations are also outlined. This we believe will help in providing future direction for research and support for sustainable rice postharvest system in Nigeria.

## 2. Rice Postharvest Value-Chain in Nigeria

To clearly understand the current status, constraints and possible opportunities that exist in the rice postharvest system in Nigeria, it is very important to have clear knowledge of the post-harvest value chain. The adaptation of value-chain approach for the systematic management of rice production and postharvest in Nigeria has facilitated increased production as a result of the adoption of improved high yielding varieties that command high price in the market and also due to huge government investment in rice production [1] [14]. With the increased yield per hectare, postharvest losses that have been relative small in absolute terms have increased proportionally with increased farm yield. Therefore, integrated management of postharvest operations such as threshing, cleaning, drying, parboiling, milling, grading and branding and storage have now become interrelated, forming a web as outlined in **Figure 1** [15]. Several technologies are being developed and out-scaled for the improvement of each operation [16]. Through the adoption of improved postharvest technologies and practices, harvested paddy is now properly threshed, cleaned, parboiled, milled and packaged, and have improves milling quality and competitiveness [16] [17].

**Figure 1** summarised the rice postharvest value-chain in Nigeria. Set of unit operations which harvested rice pass through from point of harvest to consumption is referred to as rice postharvest system (RPS). For a RPS to be efficient and sustainable, all operations most aimed at minimizing losses and maximize quality of the harvested rice until it reaches the final consumer. In Nigeria, the rice postharvest system consists of several actors at different levels involved in primary, secondary or tertiary processing operations to implement the value-chain approach to enhancing agricultural productivity. When these objectives are achieved, both food security and income of smallholder farmer's increase, and this is of vital importance for national economic growth and development particularly in developing countries. The RPS (**Figure 1**), indicated that the system consists of chain of several activities and actors.

When paddy is harvested, it passes through the first routes (A), before storage, it may be sold directly by farmers or aggregated by middle men or collected together by cooperative groups where this exists. Currently, at this level, little or no value addition is carried out. At the second level (B), significant level of value

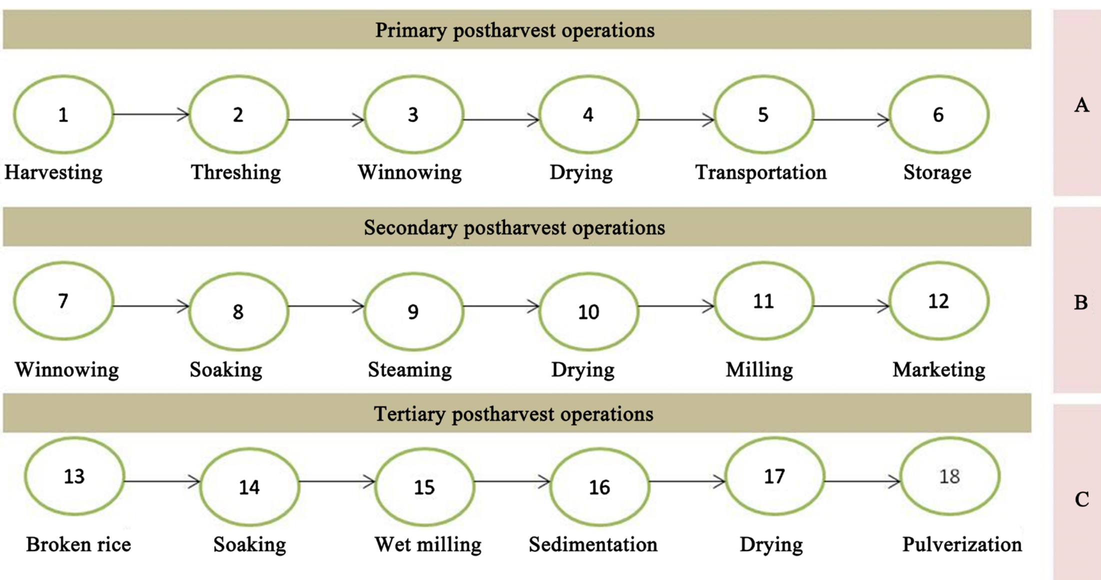


**Figure 1.** Levels in rice postharvest system of Nigeria (A = Paddy, B = white rice, C = Rice flour).

addition is made where the paddy is either milled after parboiling or directly after winnowing to produce white rice which is traded as milled rice and used for the preparation traditional whole kernel rice-based foods [4]. At this point where appropriate technologies are used, grain quality is improved and therefore economic value and competitiveness of milled rice. Recently, a third level have been added to the chain, where low grade broken fractions, a by-product of rice milling is converted to rice flour and used for the production of diverse rice-based products (C) [18]. It is important to note that only about 1% - 5% of the total rice that enters into the postharvest system is processed without parboiling [3].

During the secondary level (B), the paddy is soaked in hot water, steamed, re-dried and milled to produce parboiled whole grain rice as the final product together with broken rice, bran and husk as by-products. If milling is carried out using small village mills, the bran, husk and some small broken fractions are not separated and are often considered waste, even though there is indication that they are used as animal feeds and manure to ameliorate soil fertility [19] [20]. Several large scale integrated mills over the last ten years have been installed which combined parboiling and milling operations and coupled with grading and packaging system [21]. In these mills, parboiling and drying energy are generated by combusting the husks, while milling used electricity from national grid or private generators. The final product is colour sorted, stone free and of high quality and command premium price than the traditionally processed rice. Nigeria's current rice processing capacity is above 2.8 million tons of paddies per annum [22]. Recently, secondary processing is being developed with broken rice and other low quality rice being converted into flour and used for the production flour-based products [18] [24] [25] [26], while bran is used in combination of legumes for the production of animal feeds and sold to animal husbandry firms.

## 3. Current Status of Rice Postharvest Losses in Nigeria

In Nigeria, it has been estimated that rice post-harvest losses may be as high as 20 to 40 percent [27]. These losses are highly significant not to be considered considering production increase of about 10% per annum. RPS therefore deserves special attention if sustainable improvement is to be maintained. The Food and Agricultural Organization (FAO) of the United Nations (UN) recently estimated that rice post-harvest losses accounted for 10% to 40% of total production losses in developing countries confirming the reports of Oguntade *et al.*, [27] and implying conservatively, between 10% and 40% of the rice that is grown in Nigeria never reaches the market or consumer's table because of poor post-harvest management. Not only do these losses threatened food and nutrition security in the country, but also increases cost of production and slow down the marginal increase in yield recorded at the farm level. In other words, rice post-harvest losses if not properly mitigated, may translate not just into human hunger and financial losses to farmers, but into tremendous economic and environmental wastes as well. Because of the adoption of improved technology in agricultural production in developed countries, postharvest food losses occur primarily at the consumer level, with minimal losses at field during or after harvesting or at the other stages of the value chain [28]. In contrast, postharvest losses in developing countries like Nigeria occur mainly during harvesting through to market stages, with slightest share of losses occurring at the consumption level [28] [29].

In a recent report by Oguntade *et al.* [27], schematically presented in **Figure 2**, it was clearly demonstrated that huge losses totalling about 11.39% is recorded at paddy postharvest level, with harvesting accounting for 4.43%, threshing and cleaning (4.97%), transporting paddy from field to homes (0.34%), paddy drying and storage (1.53%) and transporting of paddy to local markets (0.12%) (**Figure 2**). At secondary postharvest levels, principally the parboiling process, an essential pre-treatment given to paddy rice before milling accounted for 5.19% paddy loss, while milling at the village level and milled rice transportation, marketing and storage results in 4.40% and 7.54% losses respectively. If this data is correlated with the rice production statistics of 17.5 MMT of paddy in 2016 [6], postharvest losses of 11.39% paddy from harvest to market and 135 Naira per Kg market price of paddy (as at November, 2018), Nigeria is currently losing about 1.99 MMT of paddy representing 269.09 billion naira annually (**Table 1**). These losses are huge and unsustainable if added up to the estimated 123 billion naira losses during the parboiling and milling processes. **Table 1** is the estimated postharvest losses in terms of quantity and quality estimated based on the 2016 paddy production estimation and loss values.

## 4. Postharvest Practices and Technologies

The use of improved techniques and intermediate technologies in the management

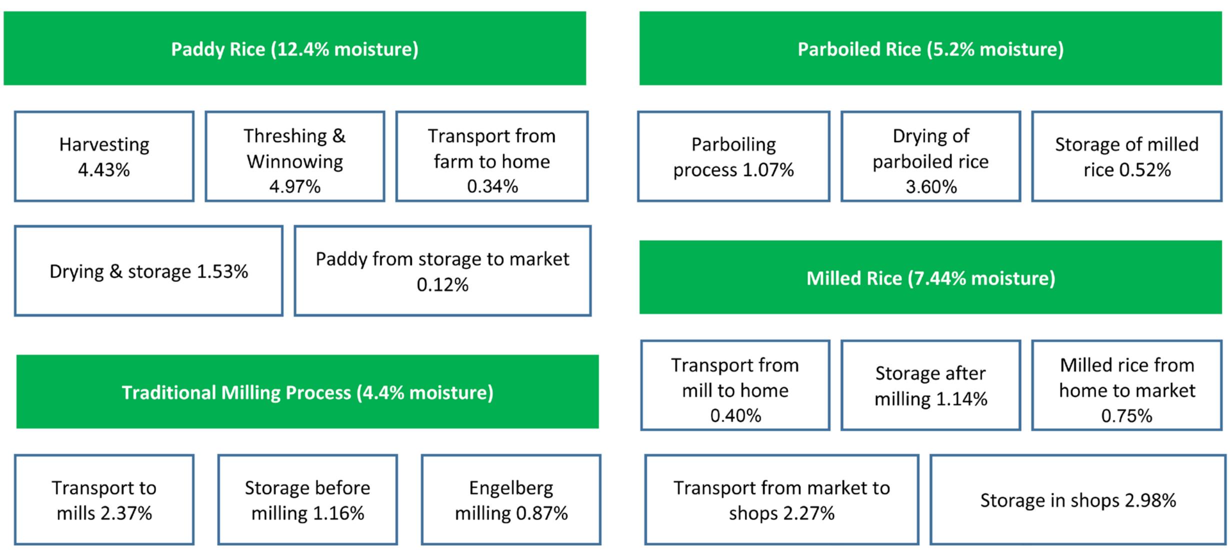


**Figure 2.** Synopsis of rice postharvest losses occurring at various postharvest levels in Nigeria [27].

Table 1. Estimated monitory cost of rice postharvest losses in Nigeria.

| Postharvest operations | PHL (%) | PHGL (MMT)[1] (×1000) | PHQL (Naira)[2] (×1000) |
|---|---|---|---|
| ***Paddy*** | | | |
| Harvesting | 4.43 | 77.5 | 104,658 |
| Threshing & cleaning | 4.97 | 86.98 | 117,416 |
| Transportation (farm to home) | 0.34 | 59.5 | 8032 |
| Drying & storage | 1.53 | 26.78 | 36,146 |
| Transporting (home to market) | 0.12 | 21.00 | 2835 |
| Sub total | **11.39** | **199.33** | **269,088** |
| ***Parboiling operations*** | | | |
| Paddy cleaning, soaking & steaming | 1.07 | 18.73 | 25,278 |
| Drying of parboiled rice | 3.06 | 535.5 | 72,292 |
| Storage of milled rice | 0.52 | 91.00 | 12,285 |
| Sub total | **4.65** | **813.75** | **109,856** |
| ***Milling (traditional)*** | | | |
| Transport to mill | 2.37 | 414.75 | 55,991 |
| Storage before milling | 1.16 | 203.00 | 27,405 |
| Milling | 0.87 | 152.25 | 20,553 |
| Sub total | **4.40** | **770.00** | **103,950** |
| ***Milled rice*** | | | |
| Transport (from mill to home) | 0.40 | 22,800 | 6840 |
| Storage after milling | 1.14 | 64,980 | 19,494 |
| Transport (from home to market) | 0.75 | 42,750 | 12,825 |
| Transport (market to shop) | 2.27 | 129,390 | 38,817 |
| Storage at shops | 2.98 | 169,860 | 50,958 |
| Sub total | **7.54** | **429,780** | **128,934** |
| Grand total | **27.98** | **3,487,580** | **583,119** |

[1]Estimated at 17.5 MMT of paddy produced in 2016, [2]estimated based on 5.7 MMT of milled rice, paddy price was 135 naira/kg and milled rice was 300 naira/kg. PHL = postharvest losses, PHGL = postharvest grain loss, PHQL = postharvest quality losses.

of rice postharvest operations has been the safest way to reduce losses and improve productivity especially among smallholder farmers [16]. In Nigeria, rice postharvest operations are mainly carried manually using rudimentary and obsolete tools which reduces efficiency, quality of milled rice and competitiveness.

## 4.1. Primary Postharvest Operations

### 4.1.1. Harvesting Practices and Technology

Harvesting is the first operation carried out once paddy is matured. Timely and proper harvesting of matured rice panicles has been demonstrated to critical because grain loss may occur as a result of possible rodent attack, lodging and/or shattering. Like in most countries of sub Saharan African (SSA), majority of rice farmers in Nigeria harvest rice using sickle, a semi-circle metal tool with a wooden handle (**Figure 3(a)**). Sickle has a smooth edge at the concave side or made with pointed zigzag edge to facilitate easy cutting. Currently, only few farmers representing about 10% use mechanical harvester and reapers, thanks to the Agricultural Transformation Agenda Programme. About 6 - 10 man days are often required to harvest a hectare of rice farm using sickle and young men are the principal labour for this operation (**Figure 3(b)**). After harvest, rice is often left on the field for few days (stalking) (**Figure 3(c)**) before bundling and transporting (**Figure 3(d)**) to a cleared portion of the field and piled round to form a circle before threshing (**Figure 3(e)** and **Figure 3(f)**). Significant losses are recorded during these operations. In some rice farming clusters, traditional or mixed varieties are cultivated, this presents farmers with the challenges of un-even plant maturity and therefore knife is used to harvest panicle by panicle, this practice is often observed in the delta region. This practice is more laborious and time consuming than the use of sickle. In many locations, large numbers of labour are engaged to reduce time of harvesting. Between 2011 and 2018, significant improvement has been made by both public and private organization in providing reapers for youths for commercial harvesting of rice and has significantly improve the operation by reducing time of harvesting and improving quality of paddy. Improved harvesting ensures good grain quality, a high market value and consumer acceptability of rice.

### 4.1.2. Threshing and Cleaning Operations

Threshing is the next operation after harvesting matured paddy. Threshing is intended to separate the paddy grains from the straw with minimal damage to the grains. If not properly handled, threshing may lead to both PHGL and PHQL


**Figure 3.** (a) farmer holding sickle, (b) harvesting using sickle, (c) harvested paddy being stalked, (d) transporting paddy to threshing ground, (e) harvested paddy formed into circle on bare ground and on plastic mat, (f) on plastic taupline ready for threshing.

losses through shattering and by mixing with other foreign matters including sand, stones, clays, seeds of other crops etc or breakage of kernel inside the husk. In Nigeria, threshing is usually done manually, even though mechanical threshing is used at large irrigated fields. The use of combine harvester has been limited by the farm size and mixed varieties cropped on the same land. Farmers mainly thresh by beating the harvested straw with wooden stick, or against metal drums (**Figure 4(a)**) or cemented vessel, tree trunks, stones etc.

Cleaning operation removes rice straw, stones, chaff and other impurities from the threshed paddy. Currently in Nigeria, threshed paddy cleaning is manually carried out by women (**Figure 4(c)**). In carrying out cleaning process, threshed paddy are thrown up along the flow of the wind leading to the blowing away of significant proportion of lighter materials. But materials having the same aerodynamic properties with rice will be retained. The process efficiency is dependent on the wind speed, experience and number of labour. Recently, through the Agricultural Transformation Agenda, National Cereals Research Institute (NCRI), Africa Rice Centre (AfricaRice), National Centre for Agricultural Mechanization (NCAM) and other private sector agricultural machinery companies have introduced and popularized mechanical thresher/cleaner in several rice production clusters (**Figure 4(b)**, **Figure 4(d)** and **Figure 4(e)**). These have improved the quality of paddy supplied to the mills and provide job opportunity for youths as this equipment is used to provide services to local farmers.

#### 4.1.3. Paddy Drying

The development of irrigation facilities in some communities especially in Kano and Kebbi and Niger States and the use of short duration improved rice varieties

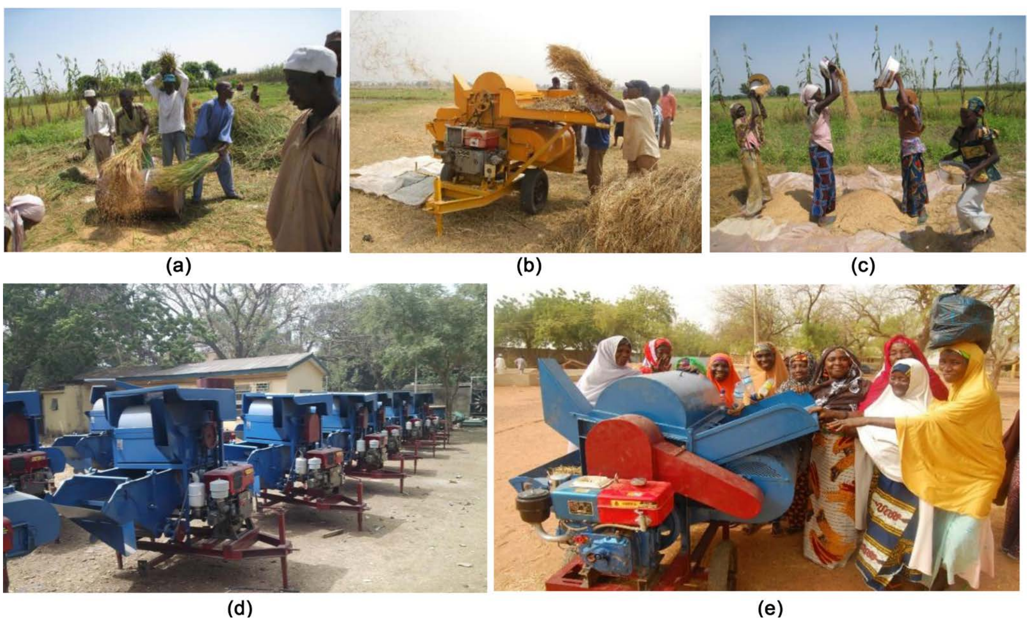


**Figure 4.** (a) Threshing paddy on drum, (b) motorized rice thresher/cleaner, (c) young girl winnowing threshed paddy manually, (d) thresher/cleaner manufacture by local artisan, (e) small thresher/cleaner adopted by women group to improve threshing and cleaning of paddy.

(FAROs 44, 52, 57, 60, 61 and 62) has provided farmers with the opportunity to plant rice twice a year. Early maturing rice varieties are mostly harvested during the rainy season and therefore drying has become one of the critical unit operations in rice postharvest. The main aim of drying paddy rice is to reduce the moisture content to safe level for storage (10% - 12%), but for steamed paddy from between 45% - 50% to 12% - 14% [21] for safe storage or milling without causing cracks or stresses on the rice kernel, which may lead to breakage during subsequent milling operation. Depending on the ecology, energy for rice drying in Nigeria is provided by direct sun light. But the efficiency of sun drying depends largely on the weather conditions. Paddy dried under high intensity sunlight for a long time may develop fissures and on milling result in high level of broken grains. Traditionally in Nigeria, rice is commonly dried on bear grown, along the high way (**Figure 5(a)**), on mats etc. most of this drying facilities expose the grains to contamination, quality and quantity losses due to spillage, animal consumption and wind. Currently, no mechanical paddy drier are available for farmers, except at the large mills for parboiled rice, even though some drying equipment (rotary dryer) (**Figure 5(e)**) have been developed by NCRI, it has not been tested and validated on industrial scale. The use of concrete platforms is being popularized (**Figure 5(b)**) to replace the traditional practices (**Figure 5(a)**) and improved platform having raised edges (**Figure 5(c)**) has been introduced to reduce spillage and improve quality.

## 4.2. Secondary Postharvest Operations

### 4.2.1. Paddy Parboiling Practices

Unlike in most part of the world, paddy harvested in Nigeria about 90% - 95% of harvested paddy is processed into parboiled milled rice before marketing. Parboiling


**Figure 5.** (a) Traditional drying on the highways, (b) drying on concrete platform, (c) improved concrete platform with raised edges to reduce spillage, (d) and (f) drying on plastic mat, (e) rotary dryer.

is a hydrothermal treatment given to paddy where it is first soaked in hot water and steamed before drying and milling [21]. In Nigeria, the traditional parboiling practices involve a lot of drudgery, and use of large quantities of water and fuel wood obtained from the forest and production of poor quality milled rice [21] [30]. This practice is not economically and environmentally sustainable [31]. Parboiling in the traditional method entails the soaking of paddy in cold water for 2 to 5 days in large clay or aluminium pots or steel drums and continuously heating the content to just below boiling point of water with the container covered with jute sack to conserve heat during the parboiling process. Periodically, the paddy is inspected until the splitting of the paddy when the heating is discontinued. The parboiled rice is then evacuated and spread out on mats or along the highways for sun drying [32] [33]. The traditional methods can take a minimum of 48 - 72 hour per batch of 50 - 100 kg paddy. This long process often allows partial fermentation or over cooking of paddy at the bottom of the vessel and consequently impacting offensive odour to the milled rice and reduced head rice recovery and consumer acceptability, hence low economic recovery.

Through constant practice most rice processors have developed their drying practices into high skilled and efficient methods of parboiled rice drying in spite of its major draw backs, such as weather conditions and losses during the drying operation [34] [35]. Sun drying is carried out on a large paved yards attached to most rice mills. A worker constantly turns and mix the paddy with wooden or plastic rake or his/her legs to achieve uniform and rapid drying. Principally, parboiled paddy is spread out (2 - 3 cm thickness) on the drying floor with a wide plastic rake. After spreading, the paddy is continuously stirred and turned. In hot and dry weather, the paddy dries in few hours, while in cold and inclement weather it may take 2 - 3 days. Where the sun energy is severe, most millers dry steamed paddy under shade away from the direct sun light [36]. In most of the communities where sun drying is practiced, steamed paddy from small home scale processors are seen being dried by the road side where stones and dust contaminate the rice and animals feed on it.

Several parboiling technologies have been developed and are adopted at different levels in different communities. National Cereals Research Institute (NCRI) (**Figures 6(b)-(d)**), National Centre for Agricultural Mechanization (NCAM), Africa Rice Centre (AfricaRice) (**Figure 6(e)**), Japan International Cooperation Agency (JICA), Hanigha Engineering Limited and other private manufacturers have developed different parboiling vessels based on principle of false bottom, reduced water and energy use and improved grain quality (**Figures 6(a)-(e)**).

#### 4.2.2. Rice Milling Operation

The milling operation is the final stage of the process of converting paddy to table rice. This is the only unit operation in rice postharvest process in Nigeria that is 100% mechanized. Mechanical rice mills and hullers are available in almost all the communities from different makes and names, but the Engelberg mill and

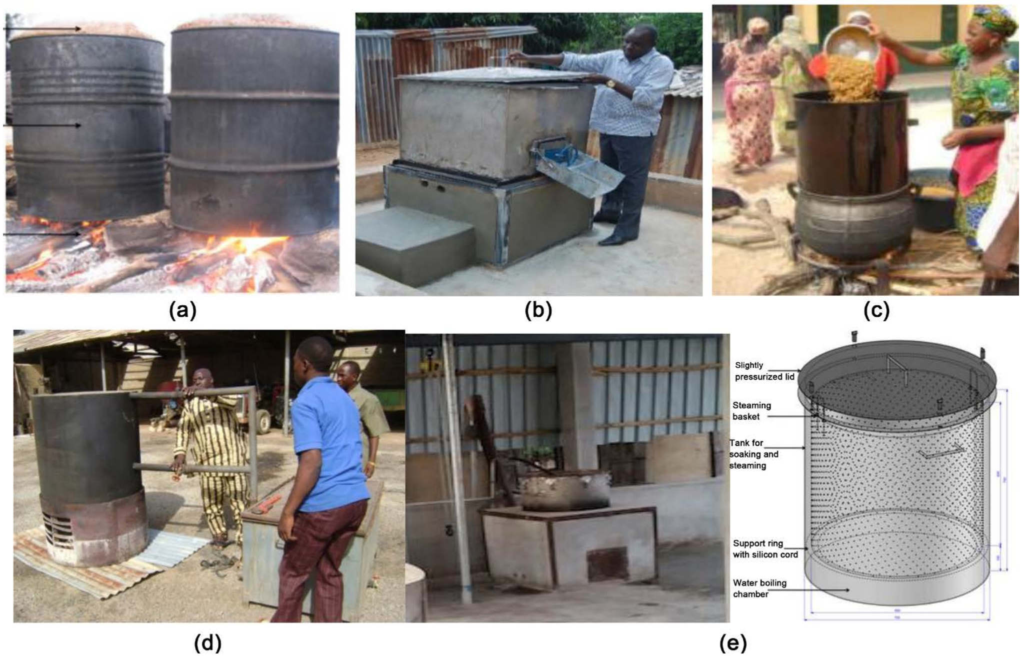


**Figure 6.** (a) traditional drum vessel, (b) NCRI self-discharge, energy and water efficient vessel, (c) NCRI small-scale perforated vessel, (d) NCRI steam parboiling drum, (e) AfricaRice GEM parboiling vessel.

rubber hullers are popular [36] [37]. Most of this equipment apart from being old are poorly installed and maintained and often deliver poor quality milled rice. Though appreciable research results have shown that when both metal and rubber roll mills are correctly set and the requisite paddy cleaning and drying are correctly done, it can give good quality milled and polished rice. Rice milling in Nigeria is dominated by small and medium scale mills. In the small scale mills, the "Cono disc" technology dominated. This technology is an old one introduced in the early 1940s. Their capacity per mill is about 0.6 tons/hour under locally manipulated conditions. The process is a one way milling system by which the paddy is hulled between two revolving metals with a metal blade forcing the rice husk to be removed mechanically. Then the rice grain with all the husk fall into lower chamber where a revolving polishing cylinder (using leather) to polishes the grains. The major challenges in rice milling is power and poor technology, though these are changing with the introduction of rubber roll mills.

#### 4.2.3. Milled Rice Grading, Branding and Marketing

Currently in the country there is no deliberate attempt by small holder rice value chain actors to grade and brand milled rice. Though in some mills, women are seen using plastic or wooden trays to grade rice if needed by the owners; only small scale destoners imported from Korea are used for experimental and demonstration purposes [36] [37]. This resulted in high level of broken and stones and other impurities in the milled rice which reduce the quality of rice milled locally. Milled rice is marketed by measured in cups, *mudus* (0.8 - 1 kg container) and bushels (15 - 16 kg container) with minimal packaging [37]. With the support of JICA and other donors like AfricaRice in collaboration with NCRI, small number of small scale rice processors have been trained on rice grading, branding and marketing, and were provided with rice grader, branded bags (5 kg, 10 kg, 25 kg and 50 kg), weighing scale and bag sawing machine to improve competitiveness [35].

## 4.3. Tertiary Postharvest Operations

### Utilization of Rice Processing By-Products

At the tertiary level, by-products of the secondary level are converted to other products through value addition. The high level of low quality broken rice fractions in locally milled rice and reported unique quality attributes of rice flour, the use of rice flour for the production of diverse rice-based products has been on the increase [18] [38] [39] [40]. The AfricaRice, NCRI, FAO and the Federal Ministry of Agriculture (FMARD) have trained over 10,000 women and youths on the production of high quality rice flour from low grade broken rice fractions and the use of rice flour in the preparation of rice-based value-added foods such as bread, cakes, porridges, noodles and other snacks is expected to increase rice demand and consumption across most countries of the world. Rice flour processed into nutritiously acceptable products is increasing market share of value added functional foods, create jobs and improve national food and nutrition security [18]. **Figures 7(a)-(d)** are high quality rice flour and some rice-based products currently being produced and marketed in Nigeria.

The use of extrusion cooking technology for the production of rice based snacks, porridges and breakfast cereals are also being popularized [18] [21] [23]. Principally the utilization of broken rice fractions for the production of rice flour and rice based products are based on valorisation of the low grade broken rice and nutritional improvement through complementation with legumes for enhanced nutrition [24] [25] [26].

With the introduction and adoption of short duration improved rice varieties at commercial level, the amount of straw, a by-product of rice production is equal to the rough rice yield based on harvest index (ratio of grain to grain plus straw). In modern rice varieties, the harvest index is 0.5, while the traditional variety is 0.3 [4]. Based on the estimated 17.5 MMT of paddy produced in 2016 [6] and the harvest index as reported by Danbaba *et al.* [4], the estimated annual


(a) (b) (c) (d)

**Figure 7.** (a) High quality rice flour, (b) packaged and branded rice flour, (c) rice flour biscuit, (d) composite formulation of rice and cowpea flour for pancake.

production of straw in Nigeria stand at 8.75 MMT. The straws and hull according to Danbaba *et al.* [4] are being used as energy sources, insulators, insect repellent and soil amelioration. The bran from integrated mills is used by feed companies for the production of animal feeds. Though rice bran is known to contain high quality oil, it is not being extracted in Nigeria probably due to the technically of the extraction process.

## 5. Synthesis of Major Constraints and Potential Mitigation Options for Rice Postharvest System in Nigeria

Several factors militating against the achievement of the full potential of rice postharvest system in Nigeria has been identified. These constraints are related to all unit operations from harvesting and cleaning, efficiency of rice milling systems, quality and quantity of rice supplied to the mills, quality of milled rice and marketing, energy for rice processing and gender related issues in rice postharvest. While vast potentials abound for improvement and investment in the sector, Table 2 presents the analysis of constraints and potentials in the rice postharvest system in Nigeria based on a field survey conducted in 2016 and recommendations made.

## 6. Opportunities for Improvement and Investments in the Rice Postharvest System

It is clear even with the huge constraints militating against the development of rice postharvest value-chain in Nigeria, there exist and open window of opportunities for improvement, investment, development, support and back stopping activities that will result in significant profit, results and impacts for sustainable rice development and improvement of livelihood. Available opportunities may include:

1) Commercial hiring of reapers, mini-combine and threshers is an opportunity for investment and employment for youths. Recent trial by Africa Rice Centre and the National Cereals Research Institute indicated those youths when properly trained and supported to provide mechanical harvesting and threshing services to smallholder farmer's results in significant improvement in quality of paddy, reduce labour cost and provide income for youths.

2) Opportunity also exists for improved seed and seed grading technology and investment in harvesting equipment. Development of community certified seed production through the provision of foundation seeds and capacity development provides a huge investment for prospective investor as seeds are often not available for farmers at the short period of planting and this often results in non-uniform paddy and loss of quality.

3) There is also huge opportunity in paddy aggregation for supply during period of short supply using system that benefits both farmers and service provider.

4) Huge opportunities are there for power supply tapping into the solar power technology.

**Table 2.** Analysis of rice postharvest constraints and proposed mitigation options.

| Constraints | Proposed mitigation options |
|---|---|
| 1. ***Factors related to rice harvesting, threshing and cleaning*** | |
| The use of sickle and knife is dominant and result in significant qualitative loss and time.<br>No mechanical harvesting is practice, except among small number of large scale producers<br>Rice cleaning is manually carried out and results in poor and inefficient cleaning operations | • Provision of small scale harvester such as reapers and mini-combine harvesters and improving capacity of smallholder to acquire them.<br>• Provision of thresher/cleaners such as ASI Thresher.<br>• Establishment of reward system for quality at all stage of rice production and processing |
| 2. ***Problems related to quantity and quality of rice supplied to mills*** | |
| Non homogeneity of the paddy supplied to the mills for processing results in poor quality milled rice.<br>Poorly dried parboiled rice results in grain heating up during milling.<br>Contamination of paddy with stones, metals, straws, seeds of other crops and other materials.<br>Short supply of paddy during certain period of the year | • Use of good quality seeds by farmers.<br>• Adoption of quality standard in the marketing of paddy.<br>• Use of rice thresher/cleaner during rice harvesting.<br>• Provision of cooperative aggregation centers.<br>• Establishment of reward system for quality at all stage of rice production and processing. |
| 3. ***Problems related to technical efficiency of rice mills*** | |
| Unreliable power supply and high cost of diesel fuel to run milling machines and engines.<br>Lake of and high cost of machine spare parts and frequent breakdown of rice mills and diesel engines.<br>Poor knowledge among rice mill operators on proper operational methods for the mills.<br>High level of stones and other impurities in paddy received at the mills. | • Possible development of solar powered motor to turn mills as in solar powered water pumps.<br>• Provision of electric power to area where this is not available at present and provision of dedicated power line to the mill sites.<br>• Capacity building for operators and provision of paddy cleaning machine at mills.<br>• Sensitization of farmers on good postharvest practices especially threshing and winnowing. |
| 4. ***Problems related to quality of milled rice and marketing.*** | |
| High percentage of broken and partially milled rice in finished product.<br>Poor market channel and standard measure.<br>Lack of proper packaging and branding of locally milled rice.<br>Poor and high cost of transportation system. | • Development of value addition technology for broken rice processing into products that command better price.<br>• Develop of proper marketing channel either through cooperative or system that will benefit the farmers, processor and consumers.<br>• Encourage private sector investment in packaging and branding of locally processed rice.<br>• Provision of soft loans vehicles for rice processors' group to ease movement of paddy from point of production to mills and from mills to market |
| 5. ***Problems related to rice parboiling and drying*** | |
| Use of poor and inefficient parboiling practices and technology<br>Lack of enhance knowledge on improved parboiling practices and quality assurance during parboiling<br>Poor drying technology and technique resulting in poor milled rice | • Dissemination and adoption of improved low cost parboiling technology<br>• Enhancement of processors knowledge on good manufacturing practices (GMP) in rice processing for good quality products.<br>• Demonstration of simple and adoptable technology for parboiled rice and drying that enhance quality |
| 6. ***Problems relating to gender in rice postharvest system*** | |
| Rice harvesting is dominated by men.<br>Rice parboiling are dominated by women<br>Milling processes are dominated by men.<br>Breaking of firewood and rice drying are mainly carried out by youths.<br>Paddy marketing is dominated by men and milled rice trade by women.<br>As scale of technology is increased, women are pushed out of rice business | • Improvement of the parboiling practices to encourage men to take part.<br>• With the current practice men are likely to dominate rice harvesting and milling for a long time to come except if the labor required is reduced.<br>• Development of efficient and environmental sustainable source of energy.<br>• If well packaged men may consider taking strategic part in marketing of milled rice<br>• Development of appropriate technology |

Field Survey, 2016.

5) Vast opportunities also exist for engineering firms and development organization to invest in production and importation of machine parts at a friendly cost.

6) High level of broken rice and poorly parboiled rice provide raw materials for the production of high quality value added rice-based products.

7) Marketing system providers can take advantage of the system to link production and market in a win-win terms for both farmers and service providers.

8) Highest opportunity exists in the provision of parboiling equipment that is energy efficient, use less water, and gender friendly in terms of capacity and produce good quality parboiled rice.

9) Marketing and development of the use moisture meter in the procurement and drying milled rice will open up opportunity for enhancing product quality and market value and milling quality.

10) Investment in destoners and paddy cleaning machines.

11) Investment in women friendly parboiling vessels and improved energy system that reduce exposure to high temperature of stove.

12) Investment in small packaging materials and cooperative marketing under a given trade name.

## 7. Contribution of Research for Development

The National Cereals Research Institute (NCRI) is one of agricultural research institutes in Nigeria established under the Federal Ministry of Agriculture and Rural development. It has the national mandate for the genetic improvement of rice among other crops such as sugarcane, fonio (acha), sesame, soybean and castor and also development of technologies for the production and postharvest improvement of rice and the overall farming system of North Central Nigeria. It also involved in the extension of its technologies through research-farmer's linkage system. The institute over the last decades have made the following contribution to rice postharvest improvement in Nigeria:

### 7.1. Provision of Good Quality Paddy through Good Quality Seeds

The improvement of the uptake of quality seed for the enhancement of the supply of good quality paddy for processing has been one of the greatest contributions of NCRI to rice farmers in Nigeria. In partnership with national and international agencies, specific quantity of foundation seeds is given to trained farmers under out-grower scheme to produce certified seed under the supervision of the institute and the National Agricultural Seed Council (NASC) that are distributed to smallholder rice farmers. Over 3000 farmers in Niger State have participated and benefited from the scheme producing over 400 - 500 tons of certified seeds. Foundation seeds are also supplied to seed companies to produce good quality certified seeds to be supplied to the farmers.

### 7.2. Development of Thresher/Cleaners for Harvested Rice

To combat problems related to rice threshing and cleaning in Nigeria, National

Cereals Research Institute (NCRI) and Africa Rice Centre in partnership with and Private sector organizations have developed and introduced improved rice thresher/cleaner. This has reduced labour requirements and eliminated back-breaking tasks for women, speed up threshing operation and produce paddy of high quality which increase its marketability. The thresher has an output of 6 - 8 tonnes of paddy per day, compared to one tonne by manual threshing with a grain-straw separation rate of 99%, no additional labour is required for sifting and winnowing. It also reduces calendar constraints to double cropping and is gender friendly. The machine has a high internal rate of return (just under 50%) and benefit cost ratio of 2.3, although the initial price of the machine is high (US$1500 to 3000).

### 7.3. Development of Paddy Cleaning Technology

As a strategy to improve the quality of paddy before storage and parboiling where mechanical thresher/cleaner is used, different paddy cleaning equipment have been developed including, pneumatic paddy cleaner, wet paddy cleaner and centrifugal cleaner to reduce the level of impurities. Adoption by smallholder processors of this technology has been low possibly due to cost as the efficiency has been tested to be high.

### 7.4. Improvement of Parboiling Vessel

Traditionally, rice is processed in Nigeria by parboiling before milling. Parboiling is carried out using simple household items, such as cooking pots, wood fires, baskets, used oil drums, large clay or aluminium pots. The resources available determine the amount of paddy parboiled per batch. Small and medium processors only parboil about 30 to 50 kg per batch. The work is time-consuming and arduous and resulting milled is of poor quality, hence command less premium. In addressing these challenges, research and development organizations have introduced simple, cost effective parboiling vessels that enable production of 100 - 700 kg per batch and provide greater control over the process.

Generally, the hot water rapid steam parboiling techniques offers a major improvement on the traditional parboiling method. The process entails the heating of paddy in a column of water in the parboiling chamber above a false bottom to about 70˚C - 75˚C and holding at this temperature for period of 4 - 6 hours. The hot water is then drained off while heating the water below the false bottom to generate steam that is distributed under pressure to the paddy mass through the steam riser main and lateral pipes. This process is then continued for about 30 - 40 minutes or till the onset of the paddy splitting is noticed during periodic inspection. The remaining hot water at the bottom of the parboiler is then drained off while the content is evacuated by either turning the vessel almost upside-down with a mechanical tipping device or the use of metal bucket and subsequently drying from approximate moisture content of 25 - 27 percent down to 14 moisture content for milling. The advantage of this method is uniformity of parboiling, short period of soaking and therefore eliminate off flavour development, amenability to small and medium scale processor and good quality milled rice. But the high cost of the vessel and risk associated with handling of steam tank has hindered significant adoption of this steam parboiling technology. In other communities a simple 100 to 150 kg parboiling vessel having perforated bottom mounted on aluminium pot are used. This technology is fast growing among smallholder farmers because of the quality of parboiled rice low cost of the vessel. Apart from increased volume of production and reduction of off flavour that characterizes traditionally parboiled rice, the new technology also has the following additional advantages:

1) Reduced firewood utilization (about 50% - 70% less the amount used in the traditional method).

2) The use of stainless steel has eliminated discoloration resulting from the use of dirty used oil or chemical drums.

3) The presence of draining pipes and taps in the improved vessels has reduced significantly drudgery associated with the traditional practices.

4) The introduction of false bottom separating the soaked paddy and steaming water ensures that paddy is steamed without coming into direct contact with water.

5) Less water is used in the improved parboiling method.

6) Soaking in hot water has also reduced the soaking time and eliminates the development of off flavour due to fermentation during cold water soaking.

7) Development of stove along with the new vessels significantly reduces exposure to intense heat.

8) The in separation of paddy and water during steaming also provide steamed rice that is wet and there reduces the drying period.

9) The new technologies are also gender friendly.

NCRI has also developed mechanical drier for the southern part of Nigeria where relative humidity is relative high throughout the year. In mechanical drying, hot air is forced through the grain which evaporates and carries away the moisture, but this technology is not widely seen in use among end-users as most complain of the cost, high technical complexity and the volume of rice required to be dried. In most of the communities, sun drying is practiced, steamed paddy from small home scale parboilers are seen being dried by the road side where stones and dust contaminate the rice and animals feed on it.

### 7.5. Improvement of Milling Technology

The National Cereals Research Institute, Badeggi have improved the steel roller mill by in cooperating cleaning component consisting of a blower and this have improved quality of milled rice from the village mills. Though few farmers have adopted this technology, the reason often given for slow uptake is the cost compared to other local mills. In Niger State only few cooperative mills are using the NCRI model and are principally funded by the Agricultural Bank of Nigeria.

### 7.6. Utilization of Rice Production and Processing by-Products

In an effort to improve the utilization of rice production and processing by-products, NCRI in-collaboration with Africa RiceCenter has developed several technologies that enhance profitability of rice system in Nigeria. Among these technologies is rice husk gasifier which uses waste product of rice milling to fire cooking stove. Some value added rice-based products are also developed and is being popularize in the country. Recently, in collaboration with Niger State ADP, NCRI organized training for 80 subject matter specialists on the production of rice flour for baking snacks. Significant results were achieving as some women are currently producing good quality rice flour from low grade broken rice fractions and this has enhanced the value of the products and its acceptability among home makers within and around the state.

### 7.7. Postharvest Insect Pest Management

Keeping rice safe from insect and pest destruction begins with good postharvest handling and management practices right from the paddy field to the storage environment. Because of reported health implication associated with the use of pesticides for crop storage, research has made it possible to develop alternative measures to minimize pesticide risks to human and agro-ecosystem health [39]. Plant products such as botanical extracts, essential oils and vegetable oils are being explored for the management of postharvest insects and pests because they are minimally toxic to plants, are synthetic, biodegradable and easily stimulate host's metabolism [40] [41].

## 8. Conclusion

Significant improvement has been made over the last few decades in terms of increasing rice productivity at farm level and several policies and programmes are being implemented to achieving the same goal, but these efforts are being hampered by poor postharvest management system resulting in huge postharvest losses. Several practices that predispose rice to high quantitative and qualitative losses in Nigeria have been identified and possible solutions and opportunity for improvement have been outlined which call for urgent attention from both national and international organizations involved in rice development. Efforts made by NCRI and its partners clearly indicated that technologies are available but are not in the hand of farmers and other actors in the rice value chain, this calls for urgent steps towards disseminating these technologies. Youth and women are co-beneficiaries of the improvement in the rice postharvest system and threshing/cleaning, parboiling and quality management during rice production and postproduction should be the first step toward achieving improved postharvest system.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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