Chapter

Advances in Rice Postharvest Loss Reduction Strategies in Africa through Low Grade Broken Rice Fractions and Husk Value Addition

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Abstract

Paddy production in African is increasing at a significantly impressive rate due to increased public and private sector investment, the introduction of high yielding varieties and improved production practices. But about 40% or more of this quantity does not reach the table of consumers largely due to post-harvest losses. These losses are subdivided into physical grain loss (PGL) and grain quality loss (GQL). Efforts towards reducing these losses through valorisation of low quality rice and processing by-products has received attention over the last few years. Innovative development and out scaling of simple, cost effective, adoptable and well-defined practical technology to convert low grade milled rice to nutrient dense value-added products that could be used for family meals or weaning purposes and utilization of rice husk for energy is the new way to go. This paper reviews major advance made especially by the Africa-Wide Taskforce on rice processing and value addition and its partners in developing strategies for minimizing postharvest loss in Africa through the development of technologies for utilization of broken rice fractions and rice husk to reduce postharvest losses. Major challenges mitigating the adoption of this technologies and possible opportunities in the rice postharvest value chain that can attract investment for the improvement of rice production and reduction in rice postharvest losses are also outlined. This synthesis we believe will help in providing future direction for research and support for sustainable rice postharvest system in Africa.

Keywords: rice, Africa, postharvest losses, broken rice value addition, husk gasification, innovation

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important crop in the world in terms of total developing world production (480 x 10^6 tonnes of rough rice in 2012) and the number of consumers (3.5 billion) dependent on it as their staple food and is cultivated in over 100 countries in every continent (except Antarctica), from 53°N to 40°S and from the sea level to an altitude of 3 kilometres high [1]. In 2019, the total world rice production amounted to approximately 738.75 million metric tons

(MMT) from total harvested area of approximately 162.71 million ha, making rice the world's third most-produced cereal crop after maize (1.12 billion metric tons) and wheat (731.45 MMT) [2]. On the African continent, especially in sub-Saharan Africa (SSA), rice has become a staple food crop and constitutes major part of the human diet [3]. Over the last three decades, African countries has experienced a consistent increase in rice production and consumption demand making rice the fastest growing staple food especially among low income earners [4]. In countries such Tanzania, Niger and Nigeria transformational changes in the production practices and shift of consumer preference from other coarse grain such as corn, sorghum and millet towards rice is particularly glaring and fuelling increased local production and consumption demand. Available statistics indicated that Africa produce an estimated 20.5 million tonnes of paddy rice annually [5], and West Africa is the continent's rice powerhouse, producing about 66% of the total paddy in Africa, mostly by smallholder farmers [4].

The growth in rice production, processing and consumption in many Africa countries has been shown to have direct correlation with growing income, rapid urbanization, population growth, and change in the occupational structure of African families. It is believed that as more and more women and young girls in Africa join the workforce, and more men live and work in urban area, there is a shift toward food that is more convenient and cooks fast such as rice. Although the per capita consumption of rice is declining in many parts of Asia, in Africa, especially the SSA region, the demand for rice is increasing and at a faster rate than in any part of the world [6]. However, rice production in Africa has not kept pace with the increasing demand, resulting in huge volume of rice imported to fill the gap at a significantly high cost to Africa external reserves. Rice farmers in Africa, especially in Nigeria, Niger and Tanzania, have responded to the increasing demand for rice, as reflected in upward trends in total production in recent years [7]. But, when compared with population increases, the rice production trends are much less impressive and many of the countries are becoming increasingly dependent on rice imports, fuelled by growing production-to-consumption gaps [8].

Geographically, according to International Rice Research Institute (IRRI), Africa has the highest reserves of untapped natural resources for food production globally, especially water and land (130 million ha of inland valley) which are essential for rice production [5]. In spite of these sizeable land and favourable agro-ecological conditions, the Food and Agriculture Organization [7] and The World Bank, [9] states that significant number of population are undernourished while poverty and unemployment levels in country such as Nigeria is significantly high (69%). Added to the high level of unemployment, food insecurity and under nutrition, there is huge food losses and waste along the entire food value chain. It has therefore become imperative to make concerted efforts to reduce losses especially postharvest losses to improve food and nutrition security in Africa [10]. Huge volume of rice produced in Africa for instant like in most developing countries does not reach the table of the final consumers due to significant post-harvest losses in terms of physical grain loss (PGL) and grain quality loss (GQL) [11].

Research for development (R4D) in Africa have developed technologies and innovations and made recommendations for increasing rice productivity through the use of high yielding varieties, expansion of area under cultivation and reducing postharvest losses through good production practices and adoption of improved technologies [10, 11]. However, in most African countries, where tropical weather and poorly developed infrastructure contribute to the problem of food loss, wastage can regularly be as high as 40–50% and has been one of the key encumbrances to farmers' income and sustainable food security in this region [12, 13]. Postharvest losses have therefore contributed significantly to African's inability to attain self-sufficiency in local food production and also a huge drain to local production and food security, as colossal quantities of food, including rice are lost, year after year [13]. Globally, Gustavsson *et al*., [14] noted that about 1.3 billion tons of food are wasted or lost annually, while in the local context such as Nigeria, the country's agricultural productivity has been generally low, mostly due to post harvest losses of farm produce (20% for grains such as rice and over 40% for fruits and vegetables), and attributed these to poor post-harvest handling, inadequate agro-processing development among other critical factors.

The adoption of good agronomic practices, favourable government policies and shift in consumer preference from other staple coarse grains toward rice have fuelled increased production and yield per hectare of rice across Africa. However, postharvest losses that have been relatively small in absolute terms have increased proportionally with increased yield per ha. Therefore, integrated management of postharvest operations such as threshing, cleaning, drying, parboiling, milling, grading and branding and storage have now been adopted in many rice producing clusters to reduce losses at each stage of the chain [13].

Ndindeng *et al*, [11] observed that resolving the critical issues along the rice value chain in many SSA countries is also impeded by the lack of a simple, adoptable and well- defined practical methodology on how to estimate PGL and GQL after harvest. This makes it impossible to have credible data during the various operations along the rice value-chain. Secondly, there is also wide quality gap between imported milled rice and domestically processed rice. The locally processed rice in Africa including Nigeria tend to be of poor quality due to high level of impurities (stones, weed seeds, sand and insect residues), high level of broken fractions, variability in grain size and colour and off-flavour perceived when cooked. However, many cost effective and efficient postharvest handling machines and practices developed and recommended by R4D organizations are not available for farmers, probably due to poor extension and funding challenges. In postharvest operation such as parboiling, the use of rudimentary technologies has resulted in high losses estimated at 15–20% with high energy and water demand which contributes to the final cost of the final product and environmentally unsustainable practices because of dependent of wood fuel [10]. They recommended the valorisation of rice processing by products to enhance income for the rice value chain actors and also improve food security and sustainable environment.

Broken rice fractions, bran and husk are major by-products of rice processing operations. They account for about 25–50% by weight of milled rice depending on variety and technology of milling. In many rice producing communities in Africa, rice processing by-products such as husk and bran are generally dispose and dumped as hips of wastes in many rice processing sites with little or no environmentally friendly ways of disposal. This has resulted in dusk related health challenges for people living nearby and methane emission during its natural decomposition [15]. But research in many parts of the world including Africa has indicated that rice husk if properly harnessed can serve as good raw materials for fuel [16, 17] and low grade broken fractions could be used for the production of other value added products [10] that may increase farmer's income, safe guide the environment and improve food and nutrition security. Broken rice fractions can be converted to high quality flour and used for the production of value added products that can enhance nutrition and food security and livelihood of smallholder farmers and profitability of small-scale food processing industries [18]. It can also employ huge number of youths and women and serve as sources of employment and reduce restiveness.

This chapter will cover selected innovative techniques and technology advancement made especially by the Africa-Wide Taskforce on Rice Processing and Value Addition and its partners in developing strategies for minimizing postharvest loss in Africa through the development of technologies for utilization of broken rice fractions and rice husk to reduce rice postharvest losses in Africa. Major challenges mitigating the adoption of this technologies and possible opportunities in the rice postharvest value chain that can attract investment for the improvement of rice production and reduction in rice postharvest losses are also outlined. This synthesis we believe will help in providing future direction for research and support for sustainable rice postharvest system in Africa.

2. Understanding the rice postharvest value-chain in Africa

Rice postharvest value chain is a set of unit operations in which well matured harvested paddy rice pass through from the point of harvest to consumption. Efficient and sustainable rice postharvest value chain therefore, aimed at minimizing losses and maximizes quality of the harvested grains until it reaches the consumer [10]. At each level of the value chain, several actors are involved and different values of losses are recorded. In Africa, especially in West Africa, several actors using diverse kinds of equipment and techniques are involved in primary, secondary and tertiary postharvest operations of the rice value chain (**Figure 1**).

Losses particularly along the value chain [1–18] has been highlighted as a major source of lost in revenue and productivity among value chain actors as both quantitative and qualitative losses occur during any of the stages [19]. This is an indication that critical attention need to be given to the postharvest value chain to reduce loss in productivity and make rice production a sustainable venture. Technically, when paddy is harvested, it passes through the first routes (A), before storage, but may also be traded directly by farmers to middle men or collected together by farmers' cooperative groups where this exists before marketing at a favourable period. Currently in Africa, especially SSA, little or no value addition is carried out at the primary postharvest level. At the second level (B), some levels of value addition are 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 of traditional whole kernel rice-based foods [20]. At this point where appropriate technologies are used, grain quality is improved which translate into improved economic value and competitiveness of milled rice.

Over the last few years, in Nigeria and other African countries, several large scale integrated mills have been installed which combined parboiling and milling operations and coupled with grading and packaging system. In these mills, parboiling and drying energy are generated by combusting the husks, while milling uses electricity from national grid or private generators. 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) or other by-products such as husk are used for energy for artisanal rice parboiling and household cooking [16, 17, 21]. The tertiary postharvest level is built on broken rice, bran

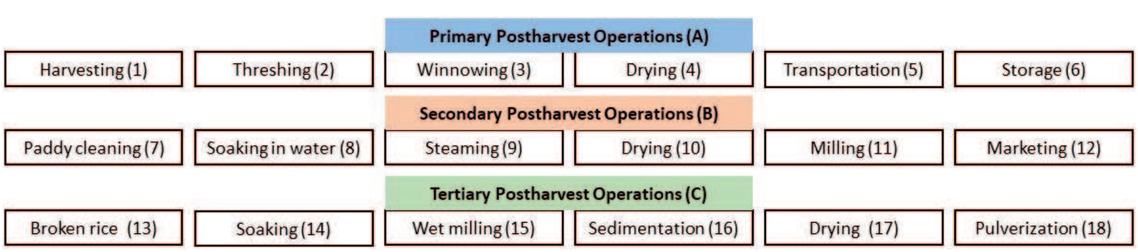

Figure 1.
Unit operations at different levels of rice postharvest system in Africa.

and husk utilization where low quality rice is converted into flour and used for the production of flour-based products, while bran is used in combination of legumes for the production of animal feeds and sold to animal husbandry firms and husk for energy sources. It is important to note that rice postharvest operations in SSA consist mainly of manual operations resulting in high crop losses and contamination.

3. Postharvest losses situation in Africa

Postharvest losses in food production including rice not only have effects on social and economic scales, but also represent a waste of resources used in production such as land, water, energy and other inputs. Report by Africa Postharvest Loss Information System [22] indicated that losses occurs hugely at all levels of the rice postharvest operations. Harvesting operations including harvesting, threshing, winnowing and drying resulted in an average of 11.2% loss due to grain spillage and poor threshing where grains are left on panicles. Transportation resulted in 2.3% (to farm and market) and storage 3.4% indicating an approximately 15.91% average postharvest loss across the continent. Report by Sallah, [23] on the postharvest losses of rice and its implication on livelihood and food security in Africa taking a case of Cameroon and The Gambia indicated that losses at threshing operation were 19 and 17%, drying 9.3 and 7.0%, storage 4.2 and 6.0%, milling 1.3 and 1.0% and transportation 1.33 and 0.8% respectively for Cameroon and The Gambia. This results in reduced income and employability of the people in the study area. Loss was aggravated by lack of or poor processing equipment, poor storage facilities, poor knowledge and skills on postharvest reduction strategies.

It has been estimated in Nigeria by Oguntade *et al*., [24] that rice post-harvest losses may be as high as 20 to 40%, implying conservatively between 10 and 40% of rice that grown in the country never reaches the market or consumers table or are traded at a discounted price due to loss of quality resulting from poor postharvest management. The high postharvest losses slowdown the marginal increase in rice production recorded over the last few years in many African countries and also threatened food and nutrition security. Because of the adoption of improved technology in rice production in developed countries, postharvest losses occur primarily at the consumer level, with minimal losses at the field or after harvesting or at the other stages of the value chain [10, 25]. In contrast, postharvest losses in Africa occur mainly during harvesting through to market stages, with slightest share of losses occurring at the consumption level [25, 26].

According to Oguntade *et al*. [24], huge losses totalling about 11.39% is recorded during rice postharvest level in Nigeria, 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%). At secondary postharvest levels (**Figure 1**), rice 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. Danbaba *et al*., [10] correlated the data with rice production statistics of 17.5 MMT of paddy produced in Nigeria in 2016 [27], considering postharvest losses of 11.39% paddy from harvest to market and 135 Naira per Kg market price of paddy (as at November, 2018), Nigeria losses about 1.99 MMT of paddy representing 269.09 billion naira annually. These losses are huge and unsustainable if added up to the estimated 123 billion naira losses during the parboiling and milling processes. Situations from the three African countries classically indicates the unfavourable postharvest loss situation on the continent which calls for urgent action and intervention.

4. Constraints and need for innovative loss reduction strategies

The continues increase in rice consumption together with minimal increase in domestic production coupled with high postharvest losses, high rice import cost and glaring impacts of climate change and conflicts in Africa, research and development organizations are working together under a coordinated strategy lead by Africa Rice Centre (Africa*R*ice) to provide innovative approach for improving productivity and food and nutrition security through postharvest loss reduction. The rapid advances in small and intermediate technology development, formulation and production of new value added products from low grade broken rice fractions and other rice processing by-products demonstrated the ability to improve food and nutrition security in Africa through novel postharvest loss reduction strategies [10, 16, 21, 28]. Until recently, rice research for development has focused on yield improvement without much emphasis on postharvest practices especially as it relates to loss reduction, quality improvement and marketability. But Nguyen and Ferrero [29] opined that in near future, the possibility of expanding rice production area will remain limited in SSA due to high cost of developing new land suitable for rice production combined with water scarcity for rice production and urban and industrial expansion, implying that loss at any point of the value chain need to minimized to save food and nutrition security in SSA.

In 2008, the SSA countries were faced with significant hike in food price [30]. Milled rice in the international market grow by almost 400% and combined with about 40% rice deficit in SSA, it become highly vulnerable to global rice prize shock and probably was the major cause of 'food riot' in 2008 in countries such as Burkina Faso, Cameroon, Cote d'Ivoire, Mauritania and Senegal [31, 32]. The riot of 2007–2008 [32] triggered renewed focus and investments in rice production together with postharvest operations in many African countries. Nigeria, Ghana, Togo, Cote d'Ivoire, The Gambia, Senegal and Burkina Faso developed a national strategic plan to attain rice self-sufficiency in medium and long time by increasing public and private sector investment into rice sub-sector of their economy, but quality and postharvest losses are least emphasised [33]. In 2011, Africa*R*ice lead a consortium of research organizations in major rice producing countries of Africa to implement and innovative postharvest loss reduction model 'enhancing food security in Africa through the improvement of rice postharvest handling, marketing and development of new rice-based products'. The project emphases the utilization of flour from low grade broken rice fractions to prepare value added food products such as snacks, biscuits, and porridges. This innovative uses of rice can catalyse rural enterprises and raise income, especially for women farmers and processors in Africa [33]. The project also developed innovative technology to utilize rice husk for energy as a strategy to add value to rice husks which are hitherto stockpiled and dumped near mills where they rot and produces methane (a potential greenhouse gas) or burned in the open fields, thus causing pollution.

By improving harvest and postharvest system of rice value chain in Africa, small holder farmer's income will be enhanced through time saving on processing, reduction in qualitative and quantitative postharvest losses which will translate to higher income and better quality of locally milled rice which may compete favourably with imported brands and fetch better price, thereby enhancing the incomes of various actors along the value chain. New rice products containing high nutrients will improve nutrition security and provide employment for women and youths and the overall industrial development of rural communities. The utilization of rice husks for energy will certainly reduce deforestation which is currently threatening significant number of countries of Africa, especially the Sahel region.

5. Innovative strategies for rice postharvest loss reduction in Africa

Innovative production is a concept that describes an on-going re-engineering process with the major aims of evolving products and production engineering from prevalent trends based on advances in research for development [34]. Innovative rice postharvest loss reduction trends in Africa is being re-engineered by evolving new value added products based on prevalent research trends. Since production innovation strengthens the productivity and resource use efficiency of production system, recent trends in Africa in the field of rice postharvest system development is the innovative approach to the utilization of rice processing by-products as a strategy to strengthen the productivity of rice and resource use efficiency. The following sections describes the innovative strategies currently used in Africa to reduce postharvest through efficient postharvest system management.

5.1 Utilization of broken rice fractions for rice flour production

Fissuring cause by poor postharvest handling of paddy results in broken kernels upon milling, and consequently lost in quality and economic values of milled rice [35]. However, recent increase in the use of rice flour has promoted interest in broken rice fractions utilization as raw materials in many foods especially snacks, porridges and others [36]. Rice flour has been used traditionally for the production of traditional stiff dough (*tuwo*) in Nigeria and many West African countries [20]. Its application in the production of high quality flour that could be used in baking has been hampered by lack of improved rice flour production process that produces flour of particles sizes that could be considered suitable as baking flour and improved functionality [21].

Chiang and Yeh [37] proposed wet milling of rice kernels to produce flour of desirable functionality. As a strategy to valorised broken rice fractions resulting from poor milling processes and rice of low grain quality characteristics, broken rice fractions are processed through wet milling process to produce high quality rice flour that has appreciably acceptable baking quality [21]. The innovative technique which is being commercialized in Africa, involves repeated wet grinding of soaked broken rice fractions and sieving through a fine cloth mesh until virtually all the slurries are made to pass through the sieve. The filtrate is allowed to stand for 3–4 hours depending on the variety and water temperature and decanted to obtain smooth sediment at the bottom. The solid sediment is broken into pieces and dried in an oven before pulverizing and sieving (200 μm) to obtain rice flour (**Figure 2**). The United States Code of Federal Regulation (CFR) state that for a product of milling of grains to be considered as flour, not less than 98% of the particles of the milling process must pass through a sieve having opening not larger than 212 μm [38]. Flour of this particle size characteristics has been demonstrated to impact positively on the end-use application [21, 38–40] studied the physicochemical and functional properties of flours from some common Nigerian rice varieties and concluded that these properties are promising for their application in food systems.

Production of flour from broken rice fraction has been shown to improve the economic value of broken rice kernels by 38% and significant consumer preference for snacks and other baked products. This has significantly reduced qualitative losses incurred during rice processing and improved income of smallholder food processors. The high quality rice flour is also blended with legume based flour (**Figure 3**) to improve protein content and quality to enhance nutrition and product specifications [21] which is an innovative production system.

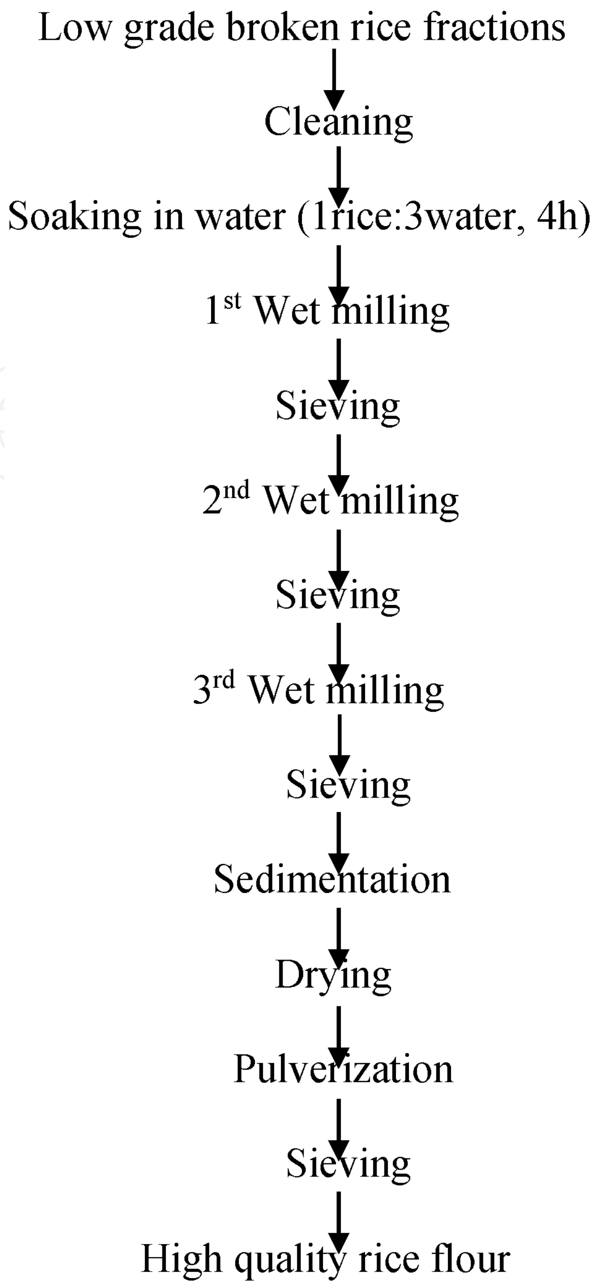

Figure 2.
Flow chart for the production of high quality rice flour from broken rice fractions. Danbaba et al. [21].

Figure 3.
High quality rice flour from broken rice fractions (left), branded rice flour (centre) and rice flour blended with cowpea flour for the production of high protein baked products [21].

5.2 Development of ready-to-eat (RTE) high protein extruded snacks and porridges from broken rice fractions

Recent changes in social life of many population across the world and the development of middle class worker in developing countries of Africa has resulted in high population of people who are inclined to eat 'ready-to-eat' food, because of its convenience, easy to consume, low to moderate price with minimal need for further processing. Extruded snacks are example of such products and their consumption is growing by day. Extrusion cooking technology is a continuous mixing, cooking and shaping process carried out at high temperatures over short times [41]. It is a very versatile, low-cost and highly energy efficient technology for snack or expanded foods production. Extrusion of cereal-based flours or other starchy raw materials is widely used in the food industry in developed countries to produce snack foods [42]. Little of extrusion cooking is being practiced in Africa especially as it relates to value added rice processing, but recent advances in rice postharvest science has introduce the use of low grade broken rice fractions as raw material for the production of extruded snack foods [10, 43].

However, when starchy raw materials such as rice are subjected to extrusion cooking, there is a chemical and structural transformation such as starch gelatinization, protein denaturation, complex formation between amylose, lipids and/or proteins, and degradation of pigments and vitamins [44]. Under the Africa-Wide Taskforce on Rice Processing and Value Addition of Africa Rice Centre and its national partners, low grade broken rice fractions from different milling operations have been tested and validated for the production of snacks that are high in protein and acceptable to consumers [21, 43]. Through process modelling and optimization, optimum moisture content, barrel temperature and level of legume flour for extrusion have been established for the blends of broken rice fractions with cowpea, bambara groundnut and soybean, keeping other extrusion parameters within range [21, 28, 43]. This optimized process conditions produces extruded snacks with smooth outer-surface (**Figure 4**) and uniform air spaces with regular shape, this according Ryu et al., [45] are features of good quality extrudates.

Because extrusion cooking process allows for the production of low-fat snacks and induces the formation of resistant starch, which makes no caloric contribution

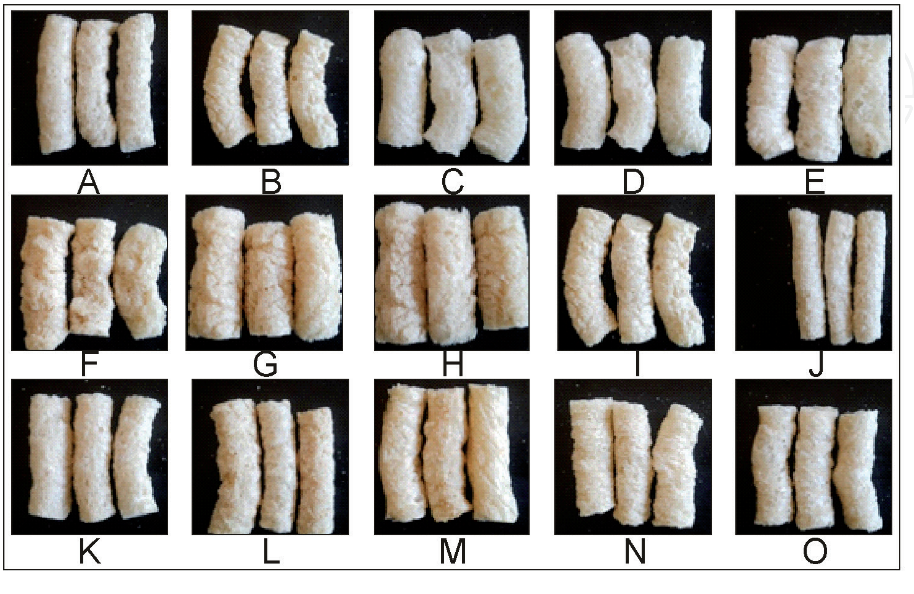

Figure 4.
Photographic images (longitudinal section) of the physical state of rice-cowpea blend extruded snacks.

and behaves physiologically like dietary fibre [46], rice-based extruded snacks in Africa have received satisfactory acceptability among consumers that are concerned with nutritional quality of food they eat. As a result, therefore, the application of extrusion cooking is increasingly becoming popular for snack production in Africa using raw materials such as rice [28, 43], sorghum [47], and millet [48] containing protein, starch and dietary fibre in an effort to create novel food products such as snacks with a more adequate nutritional value. This new product is expected to improve rice postharvest system through qualitative loss reduction and improve overall food and nutrition security of the populace.

In some instance, it has been demonstrated that when crushed and pulverized, extruded broken rice fractions could be used as porridge or weaning foods. Danbaba *et al* [21, 28] introduced extruded ready-to-eat rice porridge (**Figure 5**) as part of valorisation of low quality broken rice fractions after blending with appropriate amount of legume flour. Protein-energy malnutrition (PEM) and micronutrient deficiency is a severe problem facing developing countries and particularly children

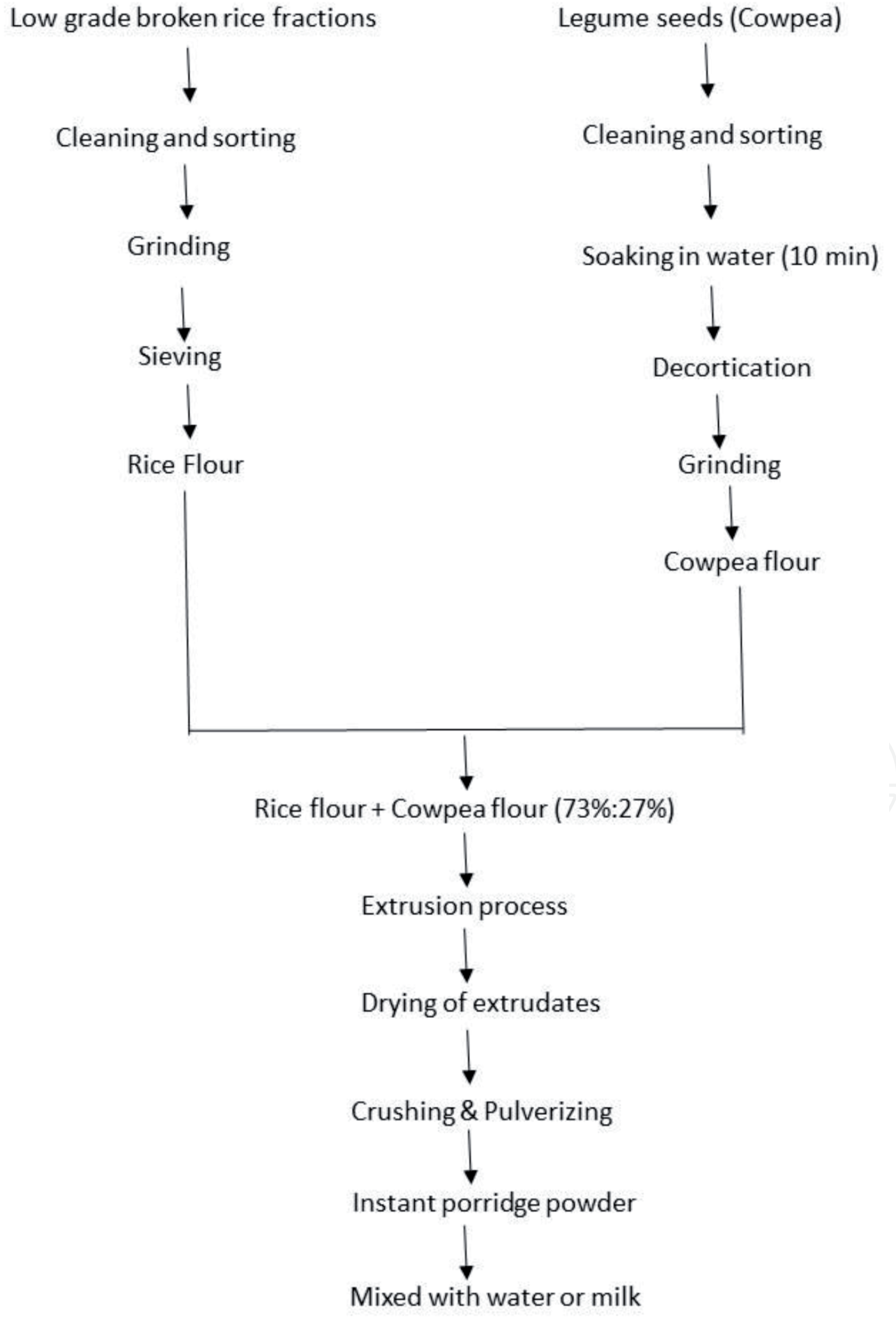

Figure 5.
Production of extruded high protein-energy weaning porridge from blends of broken rice and cowpea.

under the age of 5 years. This has resulted in more than 50% of childhood death in developing countries including Africa [49, 50]. Blending cereals with legumes in the production of complementary foods has been shown to improve childhood nutrition and significantly reduce mortality [21, 28, 43]. Several authors including Stojceska *et al*., [51]; Obradović *et al*., [52]; Panak Balentić *et al*., [53, 54] have also shown in other parts of the world that it is possible to enrich extruded cereal-based snacks with nutritionally valuable ingredients such as protein from ingredients like legumes. The utilization and application of extrusion cooking in Africa provides an alternative for producing high protein-energy weaning porridges from the blends of low grade broken rice and legumes. This process according to Pathania, *et al*., [55] credible alternative from the traditional practices for the manufacturing of re-constitutable foods for blended flours (**Figure 5**). Extrusion cooking therefore is expected to impact positively on the rice postharvest system in Africa in the years to come.

5.3 Development of third-generation snacks

The increased demand by more consumers for gluten-free products has over the few decades necessitated the quest for suitable alternative raw materials to wheat for the production of third-generation snacks, and the use of rice flour is gaining greater interest because of its favourable attributes of negligible gluten content, good expansion during extrusion and bland taste [56]. Third-generation snacks (3G), also called semi or half products, during production undergo cooking after extrusion and are dried to a stable moisture content (approximately 12%) and then expanded by frying in hot oil, puffing in hot air or microwaving and infrared heating as new variants [57]. In developed world or where extrusion cooking technology has gained popularity, 3G snacks are common. After expansion products are spiced with various types of spices and then packaged and sold as ready-to-eat (RTE) snacks [57]. The products can also be flavoured before expansion and sold as pellets, for preparation at home [58]. In Nigeria, under a strategy to improve postharvest quality of rice, especially poor quality rice varieties having poor parboiling characteristics, kernels are converted to high quality flour of specific particle size and used innovatively for the production of 3G snacks (**Figure 6**) that are current popular among snack producers in many African countries [21].

Figure 6.
Some rice-based 3G snacks produced from low grade broken rice flour.

Cold forming extrusion (40–70°C, 60–90 bar) of pre-gelatinized rice flour blended legume flour is used for the production of rice-based 3G snacks. Adjusting extrusion temperature, residence time and initial ingredient moisture facilitate complete gelatinization of starch component of the ingredients before frying [57, 59, 60]. Extruded snacks from rice will significantly take some market share as more and more countries in Africa are increasingly improving their rice production and more consumers are becoming more interested in non-gluten baked snacks. Badau *et al.* [61] state that the addition of 30% cowpea to rice flour for the production of traditional Nigeria snack (*Garabia*) significantly improves protein content, metabolizable energy and vitamin B_2, while consumer rating based on 9-point hedonic scales was above 6.0 indicating that with the addition of cowpea, the snacks are well-liked by consumers.

6. Utilization of rice husk for energy

In 2014, it was estimated that Sub-Saharan Africa produces about 22.1 million tonnes of paddy, which represent about 4.6% of the total global production [5]. Structurally, paddy consists of about 72% kernel, 5–8% bran and 20–22% husk [62]. Therefore, when 22.1 million tonnes of paddy are subjected to milling, it produces about 4.8 million tonnes of husk [11]. With the increased production of paddy in Africa over the last 2 decades, the annual production of rice husk has also proportionally increased. The utilization of rice husk for economic purposes hitherto in Africa especially SSA is very low even though by-products such as rice husk is suitable raw material for energy generation and bran is a nutritive ingredient for food formulation [11, 63]. The high amount of silica in rice husk even when mixed with bran as obtained from village mills (Engelberg type mill) is not suitable for animal feeding purposes. In SSA, significant proportion of rice husk produced is disposed of by burning in open fields or abandoned around rice milling facilities [11]. These practices have resulted in the pollution of air, land and water through the generation of greenhouses gases and particles in water and air [64]. This situation calls for urgent and innovative technique to economically utilize the husk and improve rice postharvest handling for sustainable environment.

Rice husk, a by-product of rice milling is about 20% by weight of paddy and chemically contains about 20% SiO_2. Gasification technique for rice husk as energy for rice parboiling and household cooking has been recently developed and is being commercialized across the continent of Africa [65]. Five different rice husk top-lit updraft (TLUD) gasifier household cooking stoves for use in rice processing clusters of Africa has been evaluated under a study to select technically feasible rice husk stove for rural and semi urban household cooking and artisanal rice processing in Africa. Ndindeng, *et al*. [65] study demonstrated that fan-assisted cook stoves especially PO150 recorded better thermal and emission indices and are safer to use than the natural draft gasifiers stove and is therefore recommended for household cooking in rice processing communities of Africa.

Gasification is the process of converting biomass such as rice husk into a combustible gas through thermo-chemical reaction of oxygen in the air and carbon available in the biomass during combustion. In other to gasify rice husk therefore, about 4.7 kg of air per kg of rice is needed [66, 67] and has resulted in the development of several models of fan-assisted rice husk gasifier [65]. The energy obtained are environmentally friendly and the technology easy to use by rural households. Using biomass such as rice husk in Africa for energy generation offers several advantages, including the mitigation of gaseous emissions such as CO_2, SO_x, and NO_X [68]. This is probably due to low amount of sulphur and nitrogen present in agricultural residues as well as minimal chlorine content [69]. But the question arises as to whether some components of emitted gasses by the stove during burning can contaminate the food being processed and exert toxic effects on consumers. Germaine *et al*. [70] evaluated in vivo toxicity of rice husk used as fuel for household cooking and indicated significantly non toxicity of water boiled with rice husk gasifier. The results obtained by Germaine *et al*. [70] suggested that rice husk used as fuel in household cooking using a fan-assisted rice husk stove is not toxic at 0.5, 1.0 and 2 ml/100100 g body weight and did not produce any evident symptoms in the acute and sub-chronic oral toxicity studies. Even though no evident symptom of toxicity was observed, Quispe *et al*., [69] suggested that the use of agricultural residues such as rice husk for energy purpose require the performance of integral assessment considering all stage of its life cycle and comparing same with the use of fossil fuels as a means of identifying the conditions and scenarios for a lower environmental impact. Ndindeng, *et al*., [65], McKendry, et al., [71, 72] illustrated the following as the main advantages of the innovative rice husk gasification cooking stove introduced in Africa:

1. Newly introduced rice husk stove had better performance metrics than that of existing brands in the region.

2. Rice husk mixed with palm kernel shell or other biomass significantly increase burning time but not flame temperature.

3. Data from end-user evaluation were in conformation with stove performance metrics determined instrumentally.

4. If the rice husks are completely burned, the amount of CO_2 produced is equal to the amount taken from the environment during the growing stage, making it husk gasification and environmentally sustainable practice.

5. Another advantage is the diversification of energy supply avoiding non-renewable resources depletion which is challenging African forest and farming lands.

7. Conclusion

Significant improvement has been made in Africa in terms of rice production mainly as a results of the development of new improved varieties, expansion of area under rice cultivation and huge public and private sector investments. This increased production has resulted in increased by-products such as broken rice fractions and husk. Poor utilization of the broken fractions resulted in reduction of productivity of rice and the husks have become of huge environmental and health changes. The high postharvest losses recorded in Africa has become of great concern to research and development experts, and new innovative methodologies were developed to use broken rice fractions for the production of high quality rice flour that could be used to produce high nutrients and consumer acceptable value added products that improve income and food security of smallholder rice value chain actors. The utilization of rice husk for energy generation has also become a fast moving technology where fan-assisted cooking stoves are developed and provide efficient alternative to fossil fuel. Both qualitative and quantitative post-harvest losses in rice are being aggressively managed as a strategy to improve food and nutrition security, environmental sustainability and overall productivity of rice production system. Stakeholder including policy-makers, environmental experts, among others, should as a matter of urgency priority consider the use of biomass as sources of energy for home cooking to reduce over dependence on forest woods and popularize the fan-assisted cooking stove among rural dwellers especially among populations in the Sahel region of Africa where desert is moving fast. Utilization of broken rice fraction as raw materials for flour, snacks, porridges and other foods should be encouraged as means of improving food and nutrition security as well as the socioeconomic development of rural areas.

Conflict of interest

Authors declare no conflict of interests.

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