

# Assessing Post-Harvest Losses of Rice Processing at Agricultural Business Centers (ABCs) in Rice Production in Sierra Leone

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**Abstract:** The majority of Sierra Leoneans consume rice as their primary staple food every day. The most significant staple crop worldwide and in Sierra Leone is rice (*Oryza sativa* L.), which provides nourishment for about half of the world's population. The goal of this research is to quantify post-harvest losses in rice processing at agriculture business centers (ABCs). The research experiment was carried out at eight selected functioning Agriculture Business Centers (ABCs) in eight districts across Sierra Leone. An assessment was conducted to determine the level of knowledge and farmers' awareness of post-harvest losses from harvesting to milling. A structured questionnaire was used to collect data from two hundred and thirty-two (232) rice farmers who were selected through a combination of multi-stage, purposive, and simple random sampling techniques. Yemen's (1967) scientific formula was adopted in selecting the sample size. Data analysis was undertaken using descriptive statistical tools for a phased estimation of postharvest losses. The study areas were found to be dominated by females; only 84 (36%) were males. The data showed that 92 (39.7%) of the farmers had no formal education in the research areas; the majority (63%) of the rice farmers cultivated between 1 and 3 hectares; and 98 (42.2%) had farming experience between 10 and 14 years. According to the findings, the majority of respondents (80%) believe that postharvest losses are excessive. From the results, threshing losses account for the peak of 26%, which is 0.26 kg; 92.7 percent of the respondents revealed that a lack of harvesting equipment is the main challenge; and 41.8 percent of the respondents have a strong belief that the problems of postharvest losses of rice can be significantly reduced through mechanization. The results revealed that drying losses vary significantly between parboiling methods. The values obtained for milling are different for both, but they are not significant. The values obtained from the grain quality parameters (head grain, fissuring, 1000 grain weight, chalky, and dockages) show a significant difference between the improved and traditional methods for parboiled rice at the  $\alpha=0.05$  level of significance. The study concluded that threshing losses had an adverse effect on rice farmers' income and consequently recommended awareness campaigns and demonstrations on rice handling and postharvest loss prevention.

**Keywords:** Agriculture, Rice, Postharvest, Farmers, Drying, Losses, Business, Traditional, Parboiling, Sierra Leone

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## 1. Introduction

Sierra Leone produces and consumes a large amount of rice,

which is a staple food for most Sierra Leoneans. In Sierra Leone, there is a prevalent belief that eating rice is a requirement for considering one's meal for the day to be complete. A variety of various production strategies are used

mostly by small-scale farmers to produce rice [1]. A little more than 41,300 square kilometers, or 58 percent, of Sierra Leone's total land area is devoted to agriculture; of that, 25% is considered arable land for agricultural production. Currently, just 11,510 hectares, or 15% of arable land, are being farmed [2]. About 75% of agricultural GDP is contributed by the crop subsector, with rice as the predominant staple food [3]. In the foreseeable future, it is anticipated that the demand for rice will expand at a rate of 11.8 percent each year [4]. It is also a significant economic food item, supplying nutrition, food security, and jobs for the general populace, particularly women, in both urban and rural location.

In Sierra Leone, rice is one of the most important basic foods for the rising population. Rice cultivation helps improve agricultural livelihoods, rice farmers' lives, and poverty reduction on a global scale [5]. To assist small-scale farmers in increasing yield, a number of technical remedies have been steadily introduced. For instance, in 2009 an emergency rice initiative was launched with the goal of increasing rice yield and ensuring global food security [6]. Between 2016 and 2018, the volume of rough rice produced rose, yet the demand is still not met.

Postharvest losses, which are caused by the late manner in which rice farmers harvest their crop, are the cause of these low amounts of milled rice each year. In the case of rough rice, for instance, late harvesting can result in shattering, which causes field losses, while threshing and milling might cause cracking [7]. Additionally, rough rice is often harvested at high moisture contents (MCs) of approximately 20% to 24% wet basis. This lowers field losses of rough rice (wb). On a wet basis, however, many rice farmers only harvest less than 20% of their crops [8]. Rough rice yield is decreased as a result. In order to maximize rice yield, it is essential to have rice with the ideal harvest moisture content (HMC), according to [9]. Therefore, it is necessary to look at harvesting activities and harvest moisture content in order to boost production levels.

Basically, obtaining the potential yield of rough rice depends on improvements in postharvest management at the farm level during harvesting and handling. Determining the farmers' harvesting and postharvest handling limitations as well as the causes of the losses is therefore crucial [10]. This is due to the fact that in less developed countries (LDCs), the factors regulating farm level losses typically occur before the farm gate [11]. A type of processed rice known as parboiled rice is made in certain Asian nations, most notably India, as well as in Africa, Europe, and the Americas. Paddy is hydrothermally treated before milling as part of the parboiling process. The benefit of parboiling comes from the gelatinization of rice starch and hardening of rice kernels that are brought about by the process. Therefore, fracture rates during rice milling can be reduced.

The parboiling procedure has four essential steps, which are as follows:

- i. Paddy is soaked in water (cold or moderate water) to provide moisture.
- ii. Steamed the rice to partially gelatinize it.

- iii. To preserve the moisture content for storage and milling, dry the paddy.
- iv. Brown kernels go through a mill to get the husk and bran off.

The rice after parboiling has to undergo the following physical, chemical, and nutritional changes:

- i. Due to fewer cracked kernels, the quality has increased and the milling yield has increased.
- ii. Parboiled paddy and milled rice are more durable and better preserved than raw versions. The endosperm has a tight structure that makes it resistant to attack by insects and microbes, and germination is no longer viable.
- iii. During cooking, the milled rice maintains its firmness and transforms into an unsticky texture.
- iv. During cooking, a significant amount of water is taken, causing the rice to expand.
- v. Because more vitamins and minerals have distributed into the endosperm during the parboiling process, it has a better nutritional value.

The Sierra Leone Ministry of Agriculture, Forestry and Food Security (MAFFS) released a report titled "The Agenda for Change" in 2008 that outlined a five-year strategy to further the nation's growth [3]. Following recommendations from experts and development partners, "The Smallholder Commercialization Programme (SCP)" was launched in 2010. Despite slow progress since the end of the civil war in 2001, numerous indexes still ranked Sierra Leone as one of the world's poorest and least developed nations. In the SCP, a strategy for creating an Agricultural Business Center (ABC) that would consist of numerous farmer groupings called Farmers Based Organizations (FBOs) that would eventually develop into self-sustaining Limited Liability Companies was described (LLCs) [12]. Farmers Field Schools (FFS) provided training to the members of these FBOs with a focus on adopting newer agricultural technology and techniques and better use of inputs, as well as on teaching farmers other life skills including health, nutrition, and fundamental math. The scheme was designed to put up 650 of these ABCs across the country's 13 districts. These ABCs were designed to assist in educating farmers and providing them with resources, so fostering sustainable economic growth in the agricultural sector, reducing rural poverty, and reducing food insecurity.

But according to a 2013 evaluation by the International Fund for Agricultural Development (IFAD), just 65% of the 150 established ABCs were actively working [12]. They identified recurring trends in the elements that limited ABCs' ability to grow through the examination. The Food and Agriculture Organization (FAO) then conducted an evaluation to determine which ABCs had the greatest chance of success. It was decided that the top four ABCs from each of Sierra Leone's 13 districts would go through a reform process. Because of this procedure, no attempts would be made to create new ABCs; instead, the 52 that were chosen would receive the majority of the program's attention. Assistance would be provided to them with a focus on giving access to money, producing thorough five-year plans, and training professional employees.

In Sierra Leone, there were 193 ABCs as of 2016. Following an evaluation by the Ministry of Agriculture, Forestry, and Food Security (MAFFS) and the Food and Agriculture Organization, the top 52 ABCs in the country were suggested for transformation. The ABCs that were

evaluated were chosen because, despite most ABCs failing, they nevertheless managed to succeed. The concerns noted by IFAD and the FAO evaluation criterion for these ABCs' success are shown below.

*Table 1. Agriculture Business Centers Evaluations.*

<b>2013 IFAD Report: Identified Issues</b>	<b>FAO Evaluation factor of success</b>
Lack of training in business skills	Assets management
Lack of professionals within leadership	Marketing plan
Unnecessary equipment provided	Business development
Lack of new FBOs joining ABCs	ABC location
Limited assets to spend on marketing and inputs	Business environment
Lack of good relationship with financial institutions	Governance and management
Financial management	Access to finance

### **1.1. Aim and Objectives of the Study**

The overall aim of this study is to quantify post-harvest losses of rice processing at the agriculture business centers and suggest better management techniques to overcome these losses, augment farmers' income, and sustain farmers in rice production.

The specific objectives of the study are as follows;

- i. To assess farmers' understanding on causes of yield gaps and the determinants of loss during rice processing.
- ii. To assess how recommended practice and the farmer's practices influence the rate of losses during rice processing.
- iii. To assess grain qualities after milling.

### **1.2. Statement of Problem**

Sub-Saharan Africa has a strong demand for rice due to the continent's high and rising population growth rate, and its consumption is increasing more quickly compared to any other major grain in Africa [13]. Farmers are more interested in production and focus less on the final stages of rice processing. There is a lack of detailed information about losses within the value chains of rice. In 1982, the Food and Agriculture Organization claimed that post-harvest losses of food account for 40 to 60 percent of production in Africa alone, making it the primary area of worry in the world's emerging economies.

One of the biggest issues with producing any grain, including rice, in the majority of impoverished countries is post-harvest loss. Any of the numerous post-harvest phases, including harvest, threshing, drying, storing, transport, winnowing, and milling, can result in losses in rice.

Sub-Saharan Africa is home to four of the top eleven rice-importing nations in the world, with Nigeria being the biggest [5]. In Sierra Leone, rice imports are anticipated at 480,000 metric tons in 2022, a 20 percent increase and about 25 percent above the five-year average, reflecting the lingering need to bolster the local supply following a drop in production in 2019 and 2020 and growing domestic demand [14].

Increasing tariffs on imported rice, cutting consumption—which is not an option—increasing the area now under cultivation, boosting productivity, and following

the right post-harvest procedures to reduce loss and enhance quality are all ways to lessen dependence on imports. The actual crop loss is only a portion of the issue when 20% of a harvest is lost. 20% of all inputs that went into growing the crop were also wasted, including 20% of the labor, 20% of the seeds, 20% of the fertilizer, and 20% of the water required to irrigate it. In other words, postharvest food loss causes enormous environmental waste in addition to hunger and financial loss for farmers.

### **1.3. Justification of the Study**

Post-harvest loss is becoming a more significant issue. According to the ADM Institute for the Prevention of Post-Harvest Loss, 9.2 billion people will inhabit the planet by the year 2050. While the production of food is only projected to double, food demand is predicted to rise by 70%. To satisfy the soaring demand, the agricultural industry will need to expand supply; lowering post-harvest loss presents one potential to enhance food security. Due to the staple status that rice holds in the diets of millions of people globally, post-harvest loss in rice presents a particularly significant concern.

Rice is the cereal that is grown the most widely in the world after wheat. The production of rice has provided employment for more than 20 million farmers in Africa, making it "the most significant crop for over half of the world's population." The most widely grown crop and a significant dietary staple in Sierra Leone is rice. It is crucial to lessen the amount of rice loss because of Sierra Leone's expanding population and the high rate of malnutrition there.

The issue of post-harvest loss in Sierra Leone clearly calls for response. However, there is a lacking of comprehensive data regarding losses in the rice value chains. Action on the issue is hampered by a lack of knowledge, and baseline data could ignite the necessary spark. The World Bank notes that it is frequently dangerous to start promoting post-harvest technology since they might not be the limiting factor "when suitable baselines are not established and the extent of the problem is not known."

### **1.4. Limitation**

- i. The study is limited to eight (8) of the 52 functioning

agriculture business centers in eight districts in the country, which covers only 19% of the total agriculture business centers in the country as a result of the lack of funds to cover all the 52 functioning agriculture business centers.

- ii. The study considers only postharvest losses that occur from harvesting to milling, excluding losses incurred during marketing, which could have given a comprehensive report on post-harvest loss along the rice value chain in Sierra Leone.
- iii. Also, the research was conducted during a planting session of a farming operation, which most farmers at the various Agriculture Business Centers were unable to reach.

## 2. Literature Review on Study

### 2.1. Rice Plant

The majority of Sierra Leoneans eat rice (*Oryza sativa* L.), a perennial plant that is a branch of the Graminae or Poaceae species [15, 16]. According to Moldenhauer and Slaton (2001), it features hollow and jointed culms, small, sessile leaf blades attached to the leaf sheaths by collars, and terminal panicles [17]. The key elements of the rice plant contribute to the success of its life cycle. The vegetative and floral components are among them. The spikelet is the only component of the floral part; the roots, culms, and leaves constitute the vegetative components.

According to Ranawake *et al.* (2013), the maturation of the rice plant typically takes 3-6 months depending on the type and the environment in which it is produced [18]. Beginning with the production of the coleoptile and concluding with the generation of hard dough on the panicle, it goes through a number of developmental steps. Typically, the vegetative and productive phases of the developmental cycle are distinguished. The plant is completely green during the vegetative stage, and as it reaches maturity, the straw turns golden. The vegetative phase includes emergence, seedling development, tillage, internode elongation, and culm development. The reproductive phase entails pre-booting, booting, heading, grain filling, and the maturity stage [19].

The plant produces an inflorescence, or terminal shoot, following the end of the vegetative stage (floral part). It is also known as the panicle. The flower is made up of the quantity of spikelet on the panicle [18]. This organ contains both the male (pollen-containing anthers) and female (ovary) reproductive organs. At this point, the rice plant is said to have begun to head. Self-fertilization occurs during the heading period, causing hard dough to form. The accumulation of carbohydrates in the pistils of the florets is primarily responsible for the development of the hard dough, also known as the grain.

### 2.2. The Value of Rice

According to Wayne & Dilday (2003), rice is crucial for economic growth, food security, and nutrition [20]. According to

Norman & Kebe (2004), it contains a sizable amount of protein and carbs [21]. 20% of the calories come from protein, while 3% come from fat [22]. Whole grains are the predominant form of consumption for the cereal crop. Compared to millet and other similar cereal crops, it offers more calories. According to Panday *et al.* (2010), 30% of the calories consumed in the Asian population in 2005 came from the consumption of rice [23]. About 100 million households in Africa primarily engage in rice growing as a source of energy, income, and activity [24]. One billion people on the planet are directly or indirectly involved in the cultivation of rice, according to Tran (2004) [25]. The occupation generated by rice growing contributes to increase food security. As a result, 55% of rural energy comes from agriculture, and more than 95% of rural families are fed by it [21].

In fact, the ability of the staple to support over 100 million producers has assisted in reducing poverty in communities that grow rice [23]. Consequently, when income levels rise, so do people's means of subsistence. Such livelihoods include things like sowing rice seedlings, harvesting panicles, and threshing paddy to gather it. People in rural areas can afford the costs of daily transactions and other social activities attributable to the cash generated by rice farming and post-production activities.

Its significance has sparked research into both production enhancement and the creation of drought-resistant cultivars that will help farmers cope with the country's variable rainfall patterns. As an illustration, consider how the combinational trait between *O. sativa* and *O. glaberrima* gave Nerica variety. This cultivar was created with cutting-edge technology to increase output and withstand the harsh environmental conditions and minimal input levels of African agriculture.

### 2.3. Production and Consumption of Rice

#### 2.3.1. Production and Consumption of Rice Worldwide

The present estimate of the world's population is 8 billion, but according to the United Nations' 2022 forecast, that number will increase to 8.5 billion in 2030, 9.7 billion in 2050, and 10.4 billion in 2100 [26]. This suggests that there is a need to enhance rice production globally. To meet the anticipated increase in rice demand, there is a requirement. According to estimates from Khush G. S. 2005, the world's annual raw rice production will need to increase by 40% by 2030 in order to meet the demands of the expanding global population [27].

In addition, it is anticipated that by 2025, the global production of rough rice will need to increase by at least 880 million tons, or about 70%, from its current level of 520 million tons [27]. By 2050, this requirement is likely to cause a one billion ton increase in food shortages, which will result in severe food scarcities. In terms of production and consumption, Asia is well ahead, but there aren't many more farmable regions left. This suggests that Africa might eventually have a competitive advantage. In the coming decades, there will likely be an increase in demand for rice, albeit the rate of increase will vary by location. The world's expanding human population is primarily blamed for the trend. The demand for rice is significantly influenced by factors like

rising income levels, the growth of urban areas, and consumer preferences. Globally, the amount of rice consumed per person may remain stable, but it will rise in Latin America, the Middle East, and Africa, while falling in several Asian nations whose diets are changing as a result of rising wealth and industrialization.

### **2.3.2. West Africa's Rice Production and Consumption**

In many West African families, rice has emerged as a staple food item. A significant effort has been made to advance rice research. Many African nations have also had robust breeding and selection development programs (Berhe & Mado, 2008); in regions without breeding programs, these nations gain from varieties that have been created to suit the various ecological regions [28]. The region generates roughly 8% of the calories in rice, which is grown in Sub-Saharan Africa's two main ecosystems, the rain-fed uplands and lowlands [29]. Since the 1970s, the subregion has seen an increase in rice output, which peaked at about 7 MT of milled rice at the end of the previous decade [30]. According to Fagade (2000), the increase at the production base is made up of a 30% improvement in yield and a 70% extension of the production area [31]. Despite an increase in output, there is an increasing shortage of rice in the subregion.

Over time, there has been a steady rise in the consumption of rice. According to Seck (2011), by 2050, the subregion's population would have doubled, rising from 770 million people in 2005 to 1.5 billion [32]. Production has been surpassed by the pattern of consumption. Over 10 million tons of milled rice are used annually, an increase of more than 6% on average over the previous year. A population that is expanding at a rate of 2.6% annually cannot be separated from the rise in rice consumption. In addition, rice output has shown a trend of growth at a rate of 1.1% year [30]. Since 1961, as a result, consumption has grown at a 5%–6% annual rate [33].

### **2.3.3. Evaluation of Farmer Opinions of Yield Gaps and Losses**

It is crucial to evaluate how well-informed farmers are about production gaps and postharvest losses. The method aids in determining rice farmers' understanding of post-harvest loss and the extent of yield gaps [34]. The research on rice losses has not given enough consideration to farmers' comprehension of yield and postharvest losses [35]. Biological, physiological, and economical limitations are the main causes of the decline in farm yield. During the production stage, Small-scale farmers deal with these restrictions. One such intervention is the chemical management of some biotic agents to prevent the growth of nuisances in rice fields. According to Alam and Hossain (2008), despite the adoption of better agricultural practices, rice yields in various ecosystems are not rising [36]. In addition to handling errors made when harvesting rice, biotic and abiotic stress also has a negative impact on yields. Field losses are influenced by farm-level stress.

### **2.3.4. General Rice Harvesting Operations Before and After Management of the farm is integral to rice growing. The**

management tasks on the farm have a propensity to increase output productivity, which is what needs to be done at the level of agricultural farm production. A better rice variety that can provide the highest yield at the production farm level should always be used, together with proper agricultural practices. Insecticide application, hand weeding, and bird scaring are other popular activities, particularly among women [21, 37]. Obtaining a farming space, enhancing the soil's health, and most importantly, changing the soil's shape are all tasks related to what was before operations.

At the agricultural level, postharvest activities are divided into two categories. The tasks involve cutting mature panicles and separating the food components. According to Takeshima and Salau (2010), the two classified tasks are accomplished by a physical transformation process [37]. Each point's procedures result in quantifiable losses. The activity will differ from farmer to farmer depending on the nation and the technologies available, which explains the large discrepancies in loss estimation statistics worldwide.

## **2.4. Harvesting**

When the crop is fully developed, the rice is harvested. Morphological maturity is frequently indicated by the change in color of the panicle. Additionally, during a given period of maturity, the ripening stage can be identified. For example, the majority of tropical rice cultivars reach maturity in 110–120 days. By ensuring timely harvesting, immature grain is also prevented. Because the time needed to harvest rice depends on how long the crop has been mature, harvesting should be done five days after the crop has reached that point. According to Appiah et al. (2011), the procedure is either completed by cutting the panicles or the rice stem [38].

The main obstacle to the cultivation of rice is harvesting [7]. In addition to potentially increasing the amount of rice husks produced [39], this crucial operation also has the potential to jeopardize all attempts to produce high-quality milled rice [40]. Farmers in Sierra Leone cut the rice plant from the base of the panicle, and this procedure is common in the majority of rice-producing nations worldwide. From 10 to 15 cm above the soil's surface, it is said to be sliced [41]. While harvesting is still going on, the cut straws are stacked on the field. The handling and transportation stages entail activities that result in physical losses.

### **2.4.1. Threshing Losses**

The type of procedure utilized affects the threshing losses [42]. Additionally, the approach varies from nation to nation. The techniques can be classified as manual, mechanical, or animal threading. According to Candia et al. (2012), insufficient removal of rough rice and rough rice scattering are the main causes of threshing losses [43]. According to FAO, 2007, threshing losses ranged from 2% to 6% in the Philippines and from 5% to 13% in Malaysia [44].

### **2.4.2. Paddy Cleaning**

The crucial task of paddy cleaning should be carried out not only on a big and medium mass production, but also on a small

scale. It entails separating undesired debris including weed seeds, straws, chaff, panicle, stalks, empty grains, broken and broken grains, sand, pebbles, dust, trash, and even glass and metal fragments. The paddy's level of cleanliness is, in part, a reflection of the diligence used in the reaping, crushing, and handling processes.

Rural farmers in Sierra Leone immediately clean paddy after hand threshing. They use their hands to remove straw, chaff, and other large and thick items before winnowing or causing the empty grain to fall to the ground. The process is extremely slow and is dependent on ambient air quality.

The market prices for cleaned paddy are higher than those for uncleaned paddy. In contrast, inadequate cleaning frequently leads to a higher level of pollutants in the milled rice. Another factor to take into account is that stones and other hard particles reduce the lifespan of the milling machinery. Furthermore, paddy that has not been cleaned recovers poorly from milling.

## 2.5. Parboiling

Starch undergoes an irreversible expansion and fusion during the hydrothermal treatment known as parboiling, which transforms it from its crystallized to an amorphous state. In order to do this, the rice is steeped, steamed, dried, and then ground. Rice will undergo physical, chemical, and organoleptic changes throughout the parboiling process, which will benefit the grain's economic and dietary value.

### 2.5.1. Parboiling's Consequences on Milling

The shell might crack during the milling of dry rice for a number of reasons. One of the primary causes of breaking is the processor's tendency to crack. When harvesting, threshing, or drying is delayed, cracks form. Chalky and immature kernels readily break. Milling output and quality are influenced by the type and design of the machinery. Rice breakage is influenced by milling conditions, specifically the temperature, relative humidity, and degree of milling. Breakage happens when shelling or husking activities are conducted.

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### 2.5.2. Parboiling's Impact on Nutrient Attributes

As it emerges as flakes, the bran of parboiled rice has less starch and more oil than raw rice bran. As a result, the separation of bran without endosperm loss is possible. The outer layers of rice have a higher concentration of nutrients

than the endosperm. More protein, vitamins, and minerals can be found in parboiled rice. The hydrothermal treatment is responsible for the improved nutritional availability of parboiled rice. Because the endosperm of parboiled rice receives nutrients from the higher layers, less polishing is required. After being steeped, heated, or steamed, parboiled rice contains less oil or fat. The release of oil from the kernel is assisted by specific enzymatic modifications.

### 2.5.3. Drying

According to its moisture content, the relative humidity of the air, and the ambient temperature, Paddy, as a living organism, absorbs and exudes moisture. A drop in dry matter weight, the use of oxygen, the evolution of carbon dioxide, and the release of energy in the form of heat are just a few examples of how the paddy's respiration is visible.

Paddy is typically harvested with a moisture level of 24 to 26%; during the wet season, it rises and decreases during the dry. Its rapid rate of respiration makes it vulnerable to pests, insects, and pathogens. Due to the insulating properties of the rice husk, the heat emitted during the respiration process is trapped in the grain and in the bulk, leading to losses in terms of both quality and quantity. So, when faster drying is not possible, harvested grain with high moisture content must be dried within 24hrs to 15 percent for safe storage and milling, or at most 18% for two weeks of temporary storage.

Parboiled rice that is dried too slowly may develop non-enzymatic discoloration, microbial generation, and microbial proliferation. Tarpaulins are used by little-known rural farmers to sun-dry paddy. The main limitation of sun drying is its reliance on favorable weather, which can occasionally become a serious issue, especially during the rainy season. Poor drying techniques can result in losses of 1 to 5%, with quality being the principal victim. Since it immediately influences distribution, processing quality, safe storage, and transportation, effective drying is essential for reducing postharvest losses. When employing the dry batch system, the temperature for drying paddy should not be higher than 54.40 °C for food grain. Low temperatures aid in preserving the aroma of the rice.

The following are the primary reasons for drying-related losses:

- i. While being transported to the drying facility, grains fall off of stalks or drop out of bags.
- ii. Both wild and domesticated birds normally eat grain.
- iii. Release the spill outside the drying area.
- iv. Excessive drying, particularly during solar drying.
- v. A lack of grain aeration or delayed drying, which causes the stack to catch fire.

### 2.5.4. Milling

The endosperm, which is edible, is produced during the rice milling process by separating the husk from the grain. The amount of edible grain that is lost depends on a number of variables, including the type of paddy, how it was before it was milled, how much milling was necessary, the type of rice mill used, the operator's expertise, and insect infestation. Depending on the type of rice mill used, the milling process

yields husk, milled rice, germ, bran, and broken rice as mixed goods. Wet, soft grains produce a powdery end product, whereas very dry, brittle grains produce fractured, powdery material. The optimal moisture percentage for milling is 13–14 percent.

Losses resulting from milling can be caused by:

- i. Wrongly adjusted milling machinery.
- ii. Splash back when using a typical hand hammer.
- iii. On top of or below a dry grain.

## 2.6. Techniques for Cutting Post-Harvest Economic Loss

The obvious first step in developing a suitable plan of action for minimizing postharvest economic losses is a thorough investigation of the production of all commodities, including rice, and their handling systems. When selecting technologies, the size of each postharvest enterococci must be considered [45]. Through the provision of facilities for gathering, processing, and transporting produce to markets, the coordination of marketing tactics, and the equitable distribution of earnings to members, marketing businesses and cooperatives are crucial for managing produce and lowering postharvest losses.

The most important concerns for developing nations, according to Goletti (2003), are the need for a regulatory framework that fosters growth while preserving welfare, for adequate market information to be provided to all parties involved, for increased investment in postharvest research, and for participation in international agreements that foster trade and food safety [46]. In order to calculate the return on investment for the suggested postharvest technology, a cost-benefit analysis is crucial [46]. High post-harvest losses, inadequate marketing strategies, a lack of resources for research and development, and weaknesses in laws, infrastructure, and information sharing continue to be the key obstacles [47].

According to experts, farmers might reduce losses by changing production practices, such as switching from manual gleaning to robot harvesting. But like with all agricultural decisions, an improvement's acceptance is influenced by its cost. Government measures are crucial for minimizing losses as well, particularly when it comes to staple commodities like rice and corn. According to agronomists, policies that support a steady, ample supply of these products in a free-floating, competitive market encourage food farmers to be more productive and quality-conscious De Padua, 1997 [48].

In order to prevent quality deterioration at the farm level and to gradually introduce quality standards for both paddy and milled rice, the Africa Rice Centre (ARC), formerly known as the West Africa Rice Development Association (WARDA), has recommended that priority be given to training programs for production and agricultural extension workers.

## 2.7. Evaluation of Post-Harvest Losses

Any program for reducing losses and intervening in them should include post-harvest loss assessment (Boxall, 1986) [49]. It is common for the assessment process to reveal flaws that demand immediate repair. The assessment of post-harvest

losses in sub-Saharan Africa has been the focus of numerous studies. 37% is a startlingly high estimated loss, according to IRRI (1997) [50]. Additionally, small-scale farmers, various cultivars, and environmental location have been blamed for postharvest paddy losses of 35% [11, 7].

Farms typically have the biggest post-harvest losses (World Bank et al., 2011) [51]. Physical grain loss as a result of breaking, scattering, or spilling while moving rough rice from the field is largely to blame for this. Results for estimating postharvest losses are heavily location-specific, technology- and social-behavior practice-dependent, and based on sample statistics. According to De Padua (1999), the success of loss assessment studies alerts stakeholders to the necessity of allocating funds for post-production research and also identifies key areas for study [48]. In most rice-growing areas, agricultural output has taken precedence over postharvest research. The cultivation of rough rice has a third dimension, which is postharvest research [52]. The significance of postharvest systems in the rice value chain, however, has drawn increasing attention. The lack of research in West Africa, however, is a factor in the low post-harvest technology transfer among small-scale rice producers. Researcher-identified barriers in the current postharvest system can be found through loss assessment studies.

## 2.8. Rough Rice Harvest Moisture Level (HML)

According to Qin and Siebenmorgen (2005), one of the most important variables affecting the quantity and overall economic value of rice is its relative humidity at harvest [53]. The gross income of a producer is impacted by the harvest moisture levels [55]. Rough rice output and physical losses are both impacted by the harvest's moisture content. The period to harvest rough rice is when at least 80% of the panicles have reached complete maturity, with moisture contents ranging between 20 and 24%, and the color is fully ripened (Asiedu et al., 2011) [41].

Where the panicles are harvested determines the harvest moisture levels (HML). As a result, the harvest moisture levels have an impact on the amount of rough rice present there (Bautista & Siebenmorgen, 2005; Khan & Salim, 2005) [56, 57]. The excessive loss of water molecules from the grain surfaces is made up for by the soil's moisture levels. This stops the kernels from breaking while still attached to the panicle's ears. Paddy is vulnerable to excessive breaking when there is considerable water loss, particularly in places that are rain-fed.

## 2.9. Importance of Post-Harvest Loss Reduction of Rice

Rough rice post-harvest losses affect the grain's quality or quantity. Between harvest and consumption, losses occur (Abebe & Bekele, 2006) [58]. In Sierra Leone, postharvest losses of rice are quite well known, however lowering losses of rice is typically viewed as a third factor in addition to rice production and population increase (Kader & Rolle, 2004) [52]. However, it is crucial to reduce rice loss. Additionally, the world's growing population poses a risk to feed a growing population. The extent of post-harvest losses comprises sunk

costs in addition to the physical degradation of elevated grains (the total cost of inputs used in producing lost grain).

### 2.9.1. Post-Harvest Handling Loss's Effects on Food Security

Postharvest technologies have a variety of benefits that can improve food security. By lowering post-harvest losses, they can increase the amount of food accessible for farmers and low-income rural and urban consumers. For instance, the food security of smallholders in several African countries was enhanced by the control of the bigger grain borer, which significantly decreased the loss of rice in on-farm storage. Lower pricing and more food security are two advantages for customers that result from lowering losses. Techniques for reducing food losses need to be adjusted for economic and cultural factors. This is true since a specific sociocultural setting is where all food losses take place. The problem of food losses is crucial to efforts to fight hunger, increase revenue, and enhance food security in the world's poorest communities.

Additionally, a decrease in food increases food security by raising real income for all customers [59]. However, crop production accounts for a sizable share of average income in some parts of the world (70 percent in Sub-Saharan Africa), thus decreasing food loss can directly boost farmers' wage growth [59].

### 2.9.2. Interventions to Reduce Food Waste's Effects on Food Security

Interventions to reduce food waste and food security frequently do not really explicitly link to one another. The amount of research and materials on the connection between food waste activities and food security is rather low, despite the fact that food waste interventions are very popular in policy circles. Despite the fact that there is a lot of academic and scholarly literature that asserts that food waste measures improve food security, the connection between the two factors is largely assumed. There is little research or documentation on the subject of a potential causal link between decreasing, reusing, or recycling food waste and food security, including, on the one hand, environmental factors and the natural resources required for food security.

### 2.9.3. Determinants for Rice Production

Head kernels, which are examined for quality by comparison with inspection standards samples, are grains that do not contain damaged grain, dead rice, premature grains, grains of other crops, or foreign materials. Head grains are the ones that have reached full development. Grain processing

yield rises as grain head rate raises.

The average medium- to long-grain High Yielding Survey variety includes 12 percent bran layers and 21 percent hull or husk layers. Therefore, the expected milling yield for polished grain should be 72 percent. When used with high-quality paddy and properly calibrated, modern commercial mills can produce 68 percent milled rice, with head rice (4/5 to whole grains) producing more than 72 percent. Poorly fissured paddy rice might reduce total milling yields to as little as 62 percent. A large portion of the grain endosperm is converted to rice flour, which is mixed with the bran, or to brewer's rice, which is sifted from the output of commercially milled rice. Animal feed is made from rice bran, rice flour, and small broken grains [60].

Contrarily, broken grains are ones that were discovered to be between two-thirds and one-quarter the length of a full particle. One of the most essential components in figuring out a grower's revenue is head rice recovery. The physical characteristics of the intact embryo are always of primary significance for rice's market price because it is often consumed and processed in whole kernel form. Uniformity in the physical characteristics, such as grain length, shape, and weight, also has an impact on the market value. The majority of these features are genetically influence [60].

## 3. Materials and Methods

### 3.1. Study Areas

The research experiment was carried out at eight selected functioning Agriculture Business Centers (ABCs) in eight districts across Sierra Leone. The selection of these Agriculture Business Centers (ABCs) is the result of various assessments carried out to evaluate their performances. Below are some of the criteria used to select the Agriculture Business Centers (ABCs) for this research.

- 1) These Agriculture Business Centers (ABCs) were selected for their success relative to other functioning ABCs as well as the historic involvement of external organizations in their operations.
- 2) Amount of rice processed or milled by the center.
- 3) Quantity of land used for rice production with respect to productivity.
- 4) Appropriate Agriculture Business Centers (ABCs) organization and managerial skills.

The table below shows the agriculture business centers (ABCs), location, chiefdom, district, and province visited during the research operation.

*Table 2. Agriculture Business Centers (ABCs) Locations.*

ABCs	Location	Chiefdom	District	Province
Rowala	Rowala	KholifaRowala	Tonkolili	North
Sorbeh	Makakura	Warawarayagala	Koinadugu	North
Katik	Katik Junction	Masungbala	Kambia	North
Kalomp	Lunsar	Marampa	Portloko	North
Yafami	Bo	Kakua	Bo	South
Pujehun Community for Development	Pujehun	Kpanga	Pujehun	South
Wabinaloh	Matru	Jong	Bonthe	South
Swanenehun	Moyamba Junction	Fakunya	Moyamba	South

### 3.1.1. Study Framework

Basically, the study was divided into two segments: the farmer's practice and the recommended practice (technology) at each Agriculture Business Center (ABC). The farmers' practice was carried out by the farmers themselves, from steeping to milling. The farmers were allowed to carry out their work in order to assess the quantitative loss of rice in all the stages of rice processing. The farmer's practice includes:

- 1) Winnowing before parboiling to remove the empty grains.
- 2) Direct steaming of paddy without steeping.
- 3) Drying of paddy grains on the dry floor without the use of tarpaulins or mats.

A confirmation study was conducted to assess the possible losses that do exist in every stage of rice processing. The technology is commendable. The recommended practice was carried out by the team of researchers, which I was part of. The practices (technology) carried out at each agriculture business center (ABC) include the following:

- 1) The washing of paddy thoroughly two times to remove all floating empty kernels, sand, stones, and other impurities.
- 2) Add water to the washed paddy, with water covering the paddy completely. Steep for twelve (12) hours.
- 3) Set a steam parboiler, add water to the boiling chamber, and set fire (the source of the heat) over the water to boil.
- 4) Draining and raising the paddy's steeping water.
- 5) Put steeped rice (that has been drained) in the kettle of the parboiler.
- 6) Place the loaded steam kettle in the boiler's steam compartment.
- 7) Paddy steaming until the grains split and open.
- 8) Removed parboiled paddy and spread on a clean tarpaulin in the shade for at least one hour before transferring to the sun to dry to a moisture content of 12% w/b.
- 9) Mill the dried paddy.

Among the eight Agriculture Business Centers (ABCs) visited, parboiling was done at the following centers: Rowala, Sorbeh, Pujehun Community for Development, and Kalomp for both practices.

The rice grains for both practices were spread out on the tarpaulin for the improved practice and directly spread on the drying floor for the farmer's practice after being weighed and recorded the moisture content.

For both methods, the moisture meter was used to determine the moisture content of rice before steaming and after drying at each agriculture business center (ABC).

### 3.1.2. Sampling Technique and Sampling Size

A multistage sampling approach was adopted and used to select rice farmers in the agricultural business center. Some agricultural business centers in Sierra Leone's north and south were purposefully chosen because farmers in those areas are heavily involved in rough rice production. In the second stage

of sampling, eight agricultural business centers were randomly selected for the research within eight districts in Sierra Leone, which is shown in table 2 above. In the third stage, 237 rice farmers were selected from the eight agricultural business centers, using Yemen's (1967) scientific formula for calculating sample size.

Yemen's (1967) scientific formula that was adopted in this study is given as

$$n_0 = \frac{N}{1+N(e)^2} \quad (1)$$

There was 5% room for error and a 95 percent confidence level in selecting the sample size. Where  $n_0$  is the sample size,  $N$  is the sample frame, which is 584 rice farming households, and  $(e)^2$  is the precision level (0.05).  $n_0 = \frac{584}{1+584(1-0.95)^2} = 237.3 = 237$

So a sample size of 237 rice farmers' households is our targeted population for this study. Data used in the study were collected from primary sources with the aid of a structured questionnaire and field observations.

### 3.1.3. Sources of Rice Samples

Farmers provided rice grain samples at each of the eight agriculture business centers (ABCs) visited in the country. Test samples were from the 2022 growing season.

### 3.1.4. Experiment Sample Preparation

The average initial moisture content of rice grains was 13.3% (w.b.). Before conducting the experiment, rough rice packed in a nylon bag was kept in stores at some agriculture business centers (ABCs), while at other ABCs, the rice samples were bought from other farmers in the community. At each Agriculture Business Center (ABC), the sample rice was divided into two equal portions and weighed in accordance with the amount of sample received at the ABC. One portion of the sample was given to the farmers at the Agriculture Business Centers (ABCs) to carry out their own method as explained early, and the other part was given to the team for the recommended method.

## 3.2. Parboiling Process

### 3.2.1. Steeping Condition

For the recommended practice, samples received at each agriculture business center (ABC) were processed according to the procedures explained above. This was to ensure appropriate steaming conditions and fine kernel quality.

For the farmers' practice, the rice grains were first winnowed and poured directly into the pot for steaming without steeping. See Figure 5.

### 3.2.2. Steaming Condition

The second step of the parboiling process is steaming to increase rice moisture to 30–35% w.b. Kimura et al., (1976). Steaming was done using a traditional pot for the traditional immersion parboiling method and a steam parboiled for the improved method. For the recommended practice, the sample rice was steamed for at least 112 minutes at all the ABCs where parboiling was done. See Figure 6.

### 3.2.3. Drying Conditions

The steamed rice was then dried on tarpaulins for the recommended practice and also on the dry floor by the farmers. The grains were ready for milling at an average moisture content of 13.3%. The moisture meter was used to determine the moisture content of paddy at each ABC. After drying, samples were taken to the milling room and waited for some time to ensure the appropriate cooling of the paddy before milling. See Figure 7.

### 3.3. Data Collection Instruments and Materials

The following instruments and materials were used for data collection: They include:

- 1) Moisture meter to determine the moisture content of paddy before and after drying.
- 2) A hanging scale or kitchen scale is used to measure the quantity of paddy, unloaded grains, impurities, grains left on dry floors after drying, and grain kernels.
- 3) Tarpaulin to safely dry the paddy in order to reduce moisture.
- 4) Electronic scale; measure the weight obtained from each parameter.
- 5) A magnifying glass, forceps, and lens aid in the identification of fissures and chalky rice grains.
- 6) Electronic grain counters to count the 1000-grain rice.
- 7) Transparent water plastic for rice samples.

#### 3.3.1. Determination of Losses During Drying

In accordance with the farmer's custom, paddy rice was stretched out on a drying area and further put out on tarpaulins to dry in the sun. The dried rice was gathered and collected by a skilled farmer. After the farmer had completed harvesting the dry rice, the grains that were still on the ground were gathered. Using the given equations, drying losses were calculated:

$$\text{Weight loss during drying} = \frac{\text{Weight of left over paddy}}{\text{weight of rice}} \times 100 \quad (2)$$

#### 3.3.2. Determination of Losses During Milling

Based on their yields when milling rice, several milling machines' performance was evaluated during the investigation. The quantity of polished white rice produced from dehulled rice is referred to as the "rice milling yield." The amount available at each center was milled on each machine in triplicate. Each milling machine produced rice, bran, and husk, which were gathered and weighed. The following equation was used to calculate the milling yield:

$$\text{Milling yield (\%)} = \frac{\text{Weight of white rice}}{\text{Weight of the paddy rice}} \times 100 \quad (3)$$

#### 3.3.3. Grain Quality Parameters

The properties of milled rice that were measured include:

- 1) Dockage
- 2) Whole grain
- 3) 100-grain weight
- 4) Fissure
- 5) Chalkiness

#### 3.3.4. Measurement

300 g of white rice were collected from each sample (both the farmer's practice and the improved method). The sample from each method at each Agriculture Business Center (ABC) was divided into three (3) replications, each at 100 g.

#### 3.3.5. Dockage

Dockage is the process of selecting and separating foreign materials from white rice. This was done by hand picking in the laboratory. The percentage of dockage in white milled rice was determined using the equation:

$$\text{Dockage (\%)} = \frac{\text{Weight of dockage}}{\text{Weight of white rice sample}} \times 100 \quad (4)$$

#### 3.3.6. Whole Grain

This is the separation of broken grains from whole grains of white milled rice, which was obtained through hand picking. The percentage of whole grain was determined using the formula.

$$\text{Whole grain (\%)} = \frac{\text{Weight of whole grain}}{\text{Weight of rice sample}} \times 100 \quad (5)$$

#### 3.3.7. Chalkiness

It is a visual rating of the chalky proportion of the rice grain. The chalky proportion of the grain was identified using a magnifying box, lens, and forceps. The chalky grains were selected, segregated, and weighed. The percentage of the chalky grains was determined using the equation:

$$\% \text{ chalky grains} = \frac{\text{Weight of chalky grains}}{\text{Weight of milled rice sample}} \times 100 \quad (6)$$

#### 3.3.8. Fissure

"Cracks" simply refers to cracks or openings in white milled rice. The fissures or crack grains were identified by using the magnifying box and lens. The crack grains were selected, segregated, and weighed. The percentage of fissures in the white milled rice was determined by the formula:

$$\text{Fissure (\%)} = \frac{\text{Weight of crack grains}}{\text{Weight of milled rice sample}} \times 100 \quad (7)$$

### 3.4. Data Analysis and Presentation

The data collected in the study were analyzed using one-way analysis of variance. Computer packages used included Microsoft Excel 2010. Descriptive statistical techniques were used to compute measures such as the mean and standard deviation. A t-test at the 0.05 level of significance was performed.

## 4. Results Findings and Discussions

The analysis and discussion of the study are presented in this part. The findings of this study reveal how farmers in the eight districts' agricultural business centers view rice harvesting and how to manage losses at various stages. To enhance current postharvest handling methods in Sierra Leone, the research will be used as the foundation for effective policies to be implemented with the help of the government,

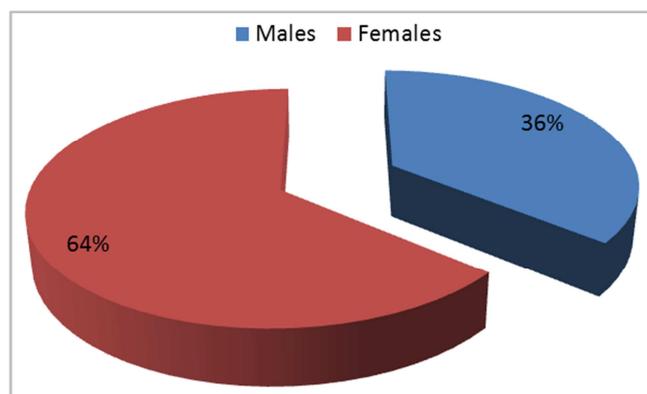
business partners, and non-governmental organizations in the rice industry.

#### 4.1. Socio-Demographic Characteristics of Rice Farmers

The field research results are presented in this section in connection to the socio-demographic details of the research participants. The participant's sex distribution, age distribution, marital status, level of education, and line of work are of particular importance to the research under this section, as will be covered below.

##### 4.1.1. Sex Distribution

The results of the investigation of the respondents' sex are shown in figure 1 below.



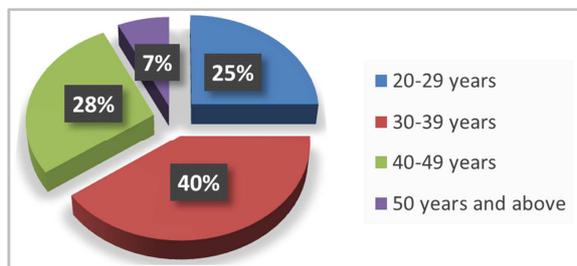
Data Source: Survey, December, 2022.

Figure 1. Sex Distributions of Respondents.

From figure 1 above, two hundred and thirty-two (232) respondents were interviewed. One hundred and forty eight 148 (64%) females and eight four 84 (36%) males participated in the study. This means that women are more engaged in postharvest processing than men. This research is in line with [13, 61], which state that in many cases, women are more active in the operations of postharvest production.

##### 4.1.2. Age Distribution

The age of the respondents was equally important and was investigated; the findings are presented in figure 2 below.



Data Source: Field survey-December, 2022.

Figure 2. Age distributions of Farmers.

Researchers conducted 232 interviews with rice growers at the Agricultural Business Centers (ABCs). Figure 2 above shows that 40% of these farmers were between the ages of 30

and 39 years as per the survey results (93). This demonstrates that the majority of farmers are in their 30s. The farmers' ages ranged from 40 to 49 years, 20 to 29 years, and 50 years and older, respectively, for 65 (28%), 58 (25%), and 16 (7%) of them. This shows that farmers had the drive and ability to grow the rice industry in Sierra Leone.

##### 4.1.3. Marital Status

As can be seen in Table 3 below, one significant socio-demographic aspect that was also looked into was the respondents' marital status.

Table 3. Marital Status of respondents.

Marital Status	Frequency	Percentage
Married	125	54
Single	62	27
Divorced	20	8
Widowed/Widowers	25	11
Total	232	100

Data Source: Field Survey-December, 2022.

On the marital status of the respondents, it was clearly shown that out of the 232 participants, 125 of them, representing 54 percent, showed that they were married, 62 (27%) of the respondents were single, 25 (11%) of the respondents are widowed or widowers, and 20 (8%) of the respondents indicated they were divorced. Abdul Salami Bah et al. (2022) made a similar suggestion [62]. Responsibility in farming households goes a long way in boosting or improving the livelihoods of farmers. Married life exposes couples to many opportunities and facilities in rural villages. Most people in rural areas are married because of the responsibilities they have in their various communities, which gives them more respect in the community.

##### 4.1.4. Educational Status

The educational status of the respondents was investigated, and the results are represented in Table 4 below.

Table 4. Educational Status of respondents.

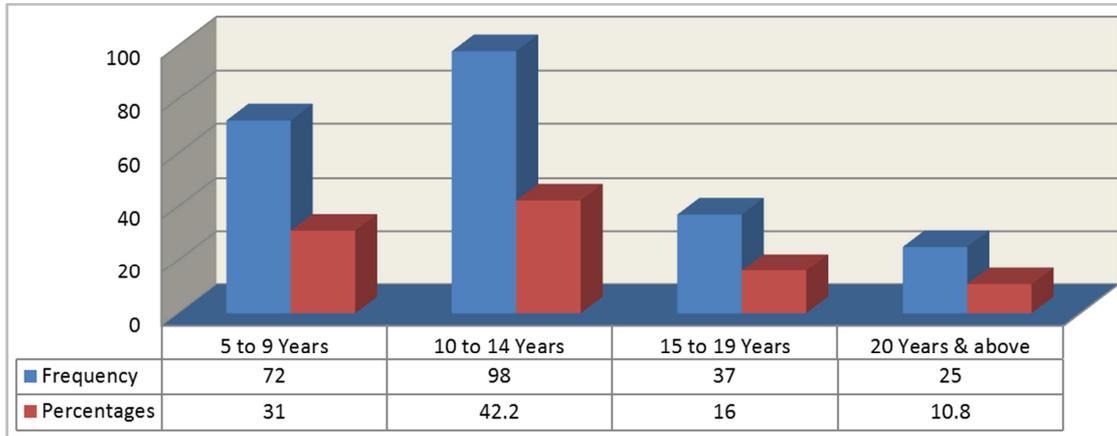
Education	Frequency	Percentage
No. Formal education	92	39.7
Quran Education	27	11.6
Primary Education	62	26.7
Secondary Education	41	17.7
Tertiary Education	10	4.3
Total	232	100

Data Source: Field Survey-December, 2022.

Table 4 shows that out of the 232 respondents, or 92 (39.7%), had no formal education, 62 (26.7%) had completed their elementary education, 41 (17.7%) had completed their secondary school, 27 (11.6%) had studied the Quran, and 10 (4.3%) had certificates or higher degrees in farm science. More education and information are good for agriculture development within any country. Therefore, farmers' access to knowledge tends to have an impact on how they handle agricultural produce [63].

**4.1.5. Farmers Experience**

This section presents the number of years of experience farmers have had in rice production.



Data Source: Survey, December, 2022.

**Figure 3. Farmers Experience.**

According to the results, 98 (42.2%) of the farmers said they had been producing rice for between 10 to 14 years, followed by 72 (31.9%) who had five to nine years of rice farming experience. 37 responses (16%) were farmers with between 15 and 19 years of experience. Additionally, 25 (10%) of the respondents were farmers who had been cultivating rice for twenty years or longer. These findings indicate that the farmers have extensive knowledge of rice production, which, if given the right resources, might contribute to the expansion of the country's rice sector.

**4.2. Farmers' Understanding of Rice Post-Harvest Economic Losses**

This section presents the findings of the field research in relation to the farmer's understanding of postharvest economic losses in rice. The stages, causes, levels, perception, and solutions to post-harvest economic losses in the rice industry are of particular interest to the research under this section.

**4.2.1. The Stages Where Rice Post Harvest Economic Losses Occur at Farm Level**

This section presents the findings of farmers' understanding of the stages where postharvest economic losses from harvesting to milling occur.

**Table 5. Stages of Post-Harvest Losses and Magnitude.**

Stages	Magnitude (Kg)	Percentages (%)
Threshing	0.26	26
Winnowing	0.20	20
Harvesting	0.13	13
Milling	0.11	11
Parboiling	0.10	10
Storage	0.08	8
Transporting	0.07	7
Drying	0.05	5
Total		100

Data Source: Field Survey-December, 2022.

According to Table 5, the stages and size of post-harvest losses in the research locations are shown. Post-harvest losses were not always understood by farmers. Ninety-six percent (96%) of the survey participants said they had lost rice after harvest, while the remaining 4% said they had not.

Twenty-six percent (26%) of the respondents said the threshing process results in the greatest losses, while 20 percent said the winnowing process results in the greatest losses. Additionally, the findings revealed that 13% of the farmers had post-harvest losses at the harvesting stage, 11% during the parboiling stage, and 8%, 7%, and 5% of post-harvest losses occurred during the storage, transporting, and drying stages, respectively. These results are different from the 2%, 6%, and 7% results for drying, threshing, and storing, respectively, that Appiah *et al.* (2011) found [39].

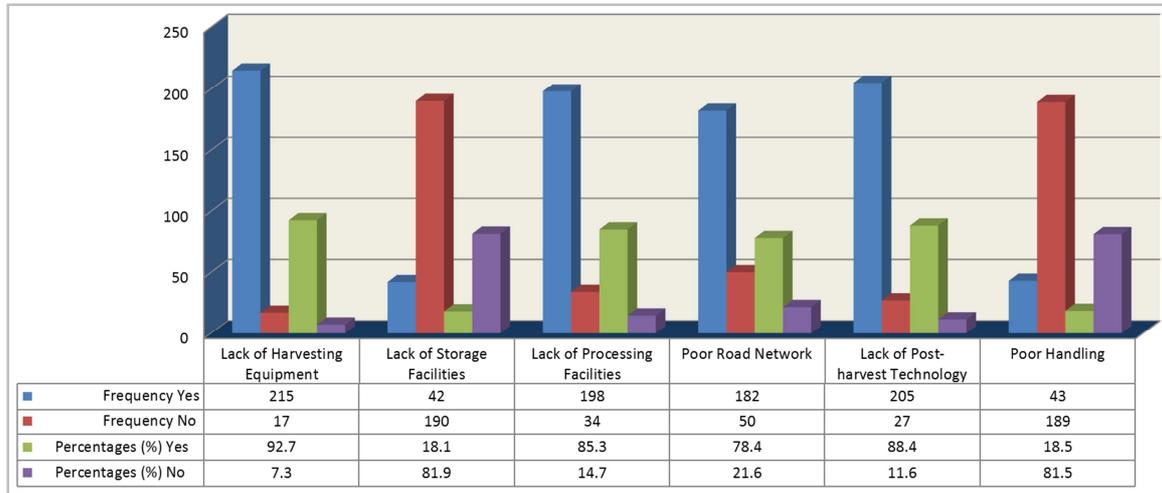
**4.2.2. The Courses of Rice Post Harvest Economic Losses at Farm Level**

The research on farmers' perceptions of post-harvest economic losses for rice in the study areas is presented in this part. The attribution factors considered ranged from the respondents' poor handling to a dearth of necessary processing equipment.

The findings showed that 92.7% of respondents said that a lack of harvesting equipment was the primary reason for post-harvest losses. According to Coker, AA *et al.* (2016), the majority of rice farmers 92.5% paid for their rice threshing out of their own personal funds and were irate that they couldn't get financial assistance from the government [64]. 88.4% of respondents said that a lack of post-harvest technologies was to blame for post-harvest losses. The dissemination of technology to farmers will aid in education, improve decision-making, and boost the amount of rough rice gathered. One of the reasons for post-harvest losses, according to 85.3% of respondents, is a lack of processing facilities. The least common reason of post-harvest losses, according to 18.1% of

the respondents, was a lack of storage space. The farmers went on to say that the main reasons for losses included floodwaters in the rice fields during harvesting when there were heavy downpours, bird attacks on the rice fields, a lack of post-harvest equipment, the need for manual labor, rice

shattering at harvesting, mold growth in the rice paddy during drying due to poor sunlight intensity and short duration of sunlight, especially during the rainy season, as well as rice breakdown during milling.

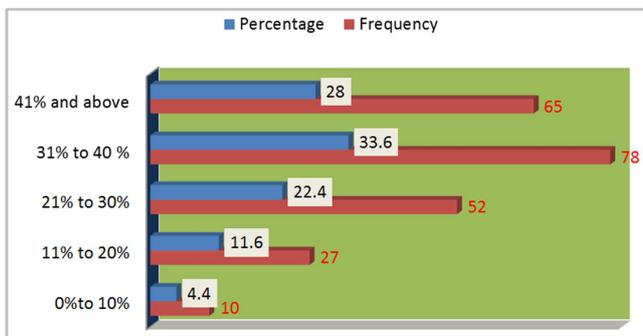


Data Source: Survey, December, 2022.

Figure 4. The courses of Rice Post Harvest Economics Losses at Farm Level.

#### 4.2.3. The Farmers Levels of Percentage of Rice Post-Harvest Economic Losses

In this part, farmers' perceptions of the magnitudes and proportions of post-harvest economic losses for rice in the research locations are presented.



Data Source: Survey-December, 2022

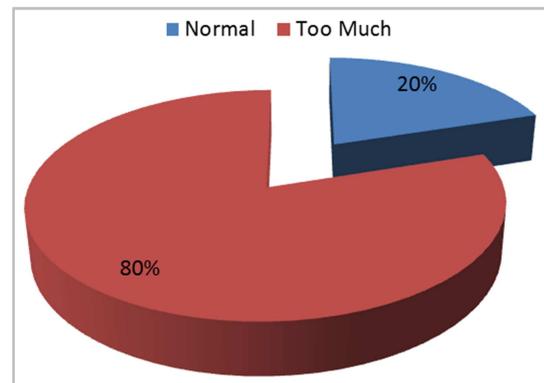
Figure 5. Percentage of Rice Postharvest Economic Losses.

The respondents' experiences with losses along the entire production cycle differed. A total of 78 respondents (33.6%) stated that their post-harvest losses vary from 31% to 40%; 65 respondents (28%), who indicated that their losses are 41 percent and higher; and 27 respondents (11.6%), who stated that their losses are between 11% and 20%. The remaining 10 (4.4%) respondents suffered losses ranging from 0% to 10%.

#### 4.2.4. The Perception Level of Farmers about Rice Post Harvest Economic Losses

This section presents the findings of the study on the perception level of farmers about rice postharvest economic

losses in the study areas.



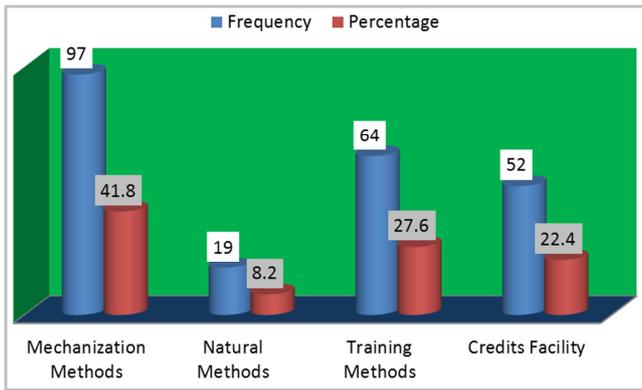
Data Source: Survey-December, 2022

Figure 6. The Perception Level of Farmers about Rice Postharvest Economic Losses.

The majority 186 (80%) of the respondents and the farmers both thought these losses were excessive. The remaining 46 (20%) people, however, believe that these losses are typical of what happens during the production process. It is clear from the rice farmers' comments that the perceived losses were excessively great. This implied that the rice farmers suffer significant losses. In order to promote industry expansion, reduce farmer poverty, and raise farmers' income, which will boost their productivity, it is crucial for everyone involved in the local rice sector to solve the staggering losses.

#### 4.2.5. The Solution to Reduced Rice Postharvest Economic Losses

This section examines the solutions farmers should use to reduce rice postharvest economic losses in the study areas.



Data Source: Survey-December, 2022

Figure 7. The Solution to reduced Rice Postharvest Economic Losses.

In an effort to lessen post-harvest losses, 97 (41.8%) of the respondents strongly believe that mechanization can help to greatly minimize the issue of post-harvest losses of rice. Unfortunately, the farmers claimed that they lacked access to automated tools and infrastructure. But 64 (27.5%) of the farmers said that training in post-harvest handling of rice would be the most crucial factor in helping to reduce thig post-harvest losses since they lacked technical understanding on the subject. Another 52 (22.4%) of the respondents who were surveyed thought that receiving financial assistance in the form of credits from the government of Sierra Leone through the Ministry of Agriculture and Food Security would enable them to purchase the necessary inputs and effective post-harvest equipment, such as combined harvesters, threshers, tractors for transporting rice, and loans to hire laborers. Unexpectedly, 19 (8.2%) of the farmers believed postharvest losses were a natural occurrence that occurred in all crops and that nothing could be done to lessen them. They contend that they won't squander money trying to stop the losses.

4.3. Quantitative Drying Losses

This section presents the findings of the farmers' quantitative drying losses that occurred at the improved and traditional methods use in rice parboiling.

Table 6. Losses from Postharvest Rice Drying.

Treatment	Quantity of rice dried (g)	Drying losses (g)	% drying losses
Improved	23000	0.97	0.004
Traditional	23000	3.42	0.014

Drying losses is the proportion of grains left on the drying floor after collection of dried paddy. From the result, an average drying loss of 0.004% (Table 6) was recorded for improved steam parboiling method and 0.014% recorded for traditional immersion parboiling during the drying loss assessment. The type of rice has no effect on drying losses. However, it depends on how skilled the farmer is. When compared to losses at other postharvest stages, the loss amount shown is small.

4.4. Efficiency of Milling Machine

The moisture content of the paddy to be milled has an impact on milling yield. The amount of moisture in the rice was measured. In order to assess the milling performance of the device, SB10 was used to mill paddy rice with an average moisture content of 12.3%, which was within the suggested range of 12–14% (Afazaliina *et al.*, 2002). In figure 8, the outcomes of the milling analyses for both approaches are shown. According to the findings, the enhanced process had a slightly higher milling yield (72% vs. 70.91%), but the difference was not very large.

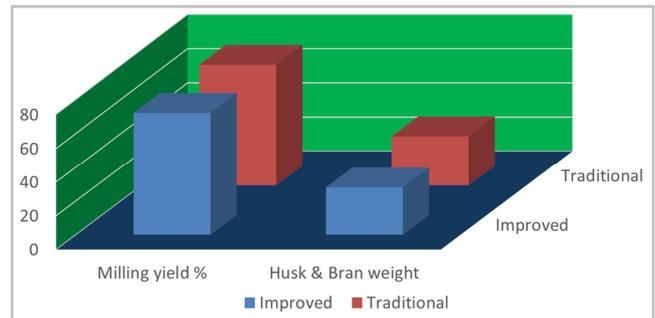


Figure 8: Milling yield of the two methods.

4.5. Qualitative Losses

This section presents the findings of the relation to the laboratory test research of processed rice after milling. Areas of particular interests to the research under this section are head rice, dockage, efficiency of milling machine, fissuring, and 1000 grain weight.

4.5.1. Head Rice

The mean percentage of the improved steam parboiling method was 28.4 and the traditional immersion parboiling method was 20.2. The mean percentage of parboiled rice was 30.8 and that of raw milled rice was 17.8. The result showed that the improved steam parboiling method and parboiled rice are more profitable to agricultural business centers and sellers because their bulkiness in a measuring cup is less. Its bulky physical quality attracts more customers than the traditional immersion parboiling method. At @=0.05, a statistical comparison revealed a significant difference between parboiling methods, parboiled and raw milled grain rice.

4.5.2. Dockage

According to the results in the table above, the traditional immersion parboiling method has a score of 6.0, while the improved steam parboiling method has a score of 0.6. The improved steam parboiling method clearly has fewer dockages than the traditional immersion parboiling method. This is because the paddy for the improved steam parboiling method was thoroughly washed and rinsed before steaming and was later spread on the tarpaulin for sun drying. The statistical comparison showed differences among the parboiling methods at a significance level of 0.05.

#### 4.5.3. Fissuring

As shown in the table above, the mean percentage of improved steam parboiling was 8.0 and the traditional immersion parboiling method was 27.8. The result shows that there are fewer fissures in improved steam-parboiled rice than in traditional immersion-parboiled rice. This is because of enough (up to 12 hours) steeping of the paddy before steaming, adequate circulation of steam during steaming, and an appropriate moisture content level of the paddy before milling. The statistical comparison showed a difference between the

parboiling methods at a significance level of 0.05.

#### 4.5.4. 1000 Grain Weight

According to the results, the mean percentage of the improved steam parboiling method was 23.3 and the traditional immersion parboiling method was 17.2. From the result, it is obvious that the improved steam parboiling method is profitable to business centers because small quantities yield heavier weight. The statistical comparison showed a difference between the parboiling methods at a significance level of 0.05.

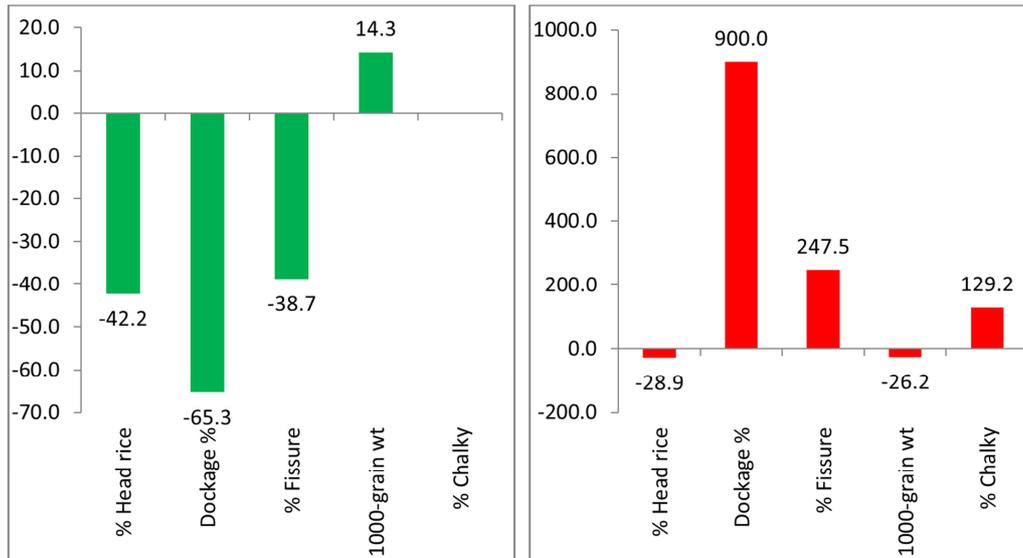


Figure 9. Relative changes in grain quality parameters showing % change due to Parboiling treatment (left panel) and Improved milling practice (right panel).

The relative baseline of parboiled rice in figure nine above (left panel), has an average change decreases in % head rice (-42.2), dockages (-65.3), fissuring (-38.7) and increase in % 1000 grain weight (14.3) of raw milled rice.

In figure nine above (right panel), relative to the baseline of improved method of rice processing, it has average change decreases in % head rice (-28.9) and 1000 grain weight (-26.2) but increases in % dockages (900), fissuring (247.5) and chalkiness (129.2) using the traditional method (direct immersion) of processing.

## 5. Discussion

An evaluation was done to see how much some rice farmers knew and understood about post-harvest losses from harvest to milling. Each of the Agriculture Business Centers' twenty-nine (29) rice producers was interviewed by the researchers (ABCs). This gives the total number of 232 respondents from the eight (8) Agriculture Business Centers.

### 5.1. Socio-Demographic Characteristics of Rice Farmers

According to the study's findings, 232 participants from the study areas were interviewed. 84 males (36%), 148 women (64%) were participants in the study. This indicates that postharvest processing is a more active activity for women

than for men. The bulk of the females were more engaged in post-harvest activities, according to Ofori Obeng Nketiah (2015), who concurred with my finding based on his observations [60].

According to the age distribution of the respondents in the research (93), 40 percent of these farmers were between the ages of 30 and 39 years. This shows that people in their 30s make up the majority of farmers. On the other hand, 65 (28%), 58 (25%), and 16 (7%) of the farmers were between the ages of 20 and 29, 40 to 49, and 50 and over, respectively. This indicates that farmers were motivated and had the capacity to develop Sierra Leone's rice sector.

In terms of respondents' marital status, 125 (54%) of the 232 participants said they were married, 62 (27%) said they were single, 25 (11%) said they were widowed or widowers, and 20 (8%) said they were divorced. Similarly, Abdul Salami Bah et al. (2022) proposed [62]. Farmer livelihoods can be significantly boosted or improved by household responsibility. In rural villages, married life exposes couples to a variety of chances and amenities. Due to their obligations to their local groups, most people in rural areas are married, which increases their status in the community.

Out of 232 respondents, 92 (39.7%) said they had no formal education, 62 (26.7%) said they had completed elementary school, 41 (17.7%) said they had completed high school, 27 (11.6%) said they had studied the Quran, and 10 (4.3%) said

they had certificates and a higher diploma in agriculture science. This implies that although most farmers took part in farm education programs, there was a low level of provision of support services.

From observation, it appears that some individual farmers did not completely utilize the organization, despite the fact that farmer-based organizations (FBOs) are well absorbed in the research region. The main benefits that these types of farmers received from community-based organizations (CBOs) were access to farm equipment and discounted inputs. The discovery was consistent with Mansuri and Rao's findings (2004) [65]. The results of this study corroborated Babalola *et al.* (2010) assertion that a farmer's membership in a community-based organization was when the farmer needed access to the market after harvest [66]. However, the creation of farm-related community organizations was meant to boost members' capacities, not only give them access to financing and markets.

It was also observed that most small-scale farmers were engaged in the production of rice. The data backs up the idea that rice farmers work on smaller farms. The research shows that 22% of the same respondents, who are rice farmers cultivate on farms with a size of 0.7 ha, compared to 43% who cultivate on farms with a size of 0.3 ha. As reported by Hazell *et al.* (2010), who claimed that the increase in non-agricultural activities has resulted in a decline in agricultural land size, the average land size of 0.66 ha suggests that agricultural farm lands have shrunk over time [67]. Additionally, the result (0.66 ha) is comparable to the results made by Onoja and Herbert (2012), who determined that an average farm size is 0.6 ha [68].

Years in the farming business: According to the findings, 98 (42.2%) of the farmers said they had been producing rice for between 10 and 14 years, while 72 (31.9%) said they had five to nine years' worth of experience. 37 (16%) of the responders were farmers with 15 to 19 years of experience. 25 (10%) of the responders were farmers who had been growing rice for twenty years or more. These findings demonstrate the farmers' extensive knowledge of rice farming, which, if supported with adequate resources, might contribute to the expansion of Sierra Leone's rice sector.

## **5.2. Stages, Causes, Perception, and Solutions of Losses Perceived by Farmers at Farm Level**

The research found that although farmers' losses were estimated by guesswork, they were aware that losses did happen on a farm level. Post-harvest losses were not always understood by farmers. Ninety-six percent (96%) of the survey participants said they had suffered post-harvest rice losses, while the remaining 4% said they had not. Twenty-six percent (26%) of the 232 respondents said that the threshing process results in the most losses, and five percent (5%) said that drying results in the least postharvest losses. These results are different from the 2%, 6%, and 7% results for drying, threshing, and storing, respectively, that Appiah *et al.* (2011) found [39].

The findings also showed that 92.7% of respondents believed a lack of harvesting equipment to be the primary factor in post-harvest losses. According to Coker, AA *et al.* (2015), the majority of rice farmers 92.5% of the respondents paid for their rice threshing out of their own personal funds and were irate that they couldn't get financial assistance from the government. The least common reason of post-harvest losses, according to 18.1% of the respondents, was a lack of storage space.

The lowest proportion of postharvest losses was reported by 10 respondents (4.4%), who reported losses of 0% to 10%. Seventy-eight and 78 respondents (33.6%) reported total postharvest losses of 31% to 40%. The majority (80%) of the respondents and the farmers both thought these losses were excessive. The remaining 46 (20%) people, however, believe that these losses are typical of what happens during the production process. It is clear from the rice farmers' comments that the perceived losses were excessively great. Since 61.6% of rice farmers reported losses of 31% or more, it is implied that the farmers suffer significant losses. In order to promote industry expansion, reduce farmer poverty, and raise farmers' income, which will boost their productivity, it is crucial for everyone involved in the local rice sector to solve the staggering losses.

The problem of post-harvest losses of rice can be greatly reduced, in the opinion of 97 (41.8%) of the respondents, through mechanization, whereas 19 (8.2%) of the farmers think that post-harvest losses are a natural occurrence occurring in all crops and that nothing can be done to lessen them. They assert that they won't squander money attempting to contain losses.

It is critical for players in the local rice sector to talk about these large losses in order to promote the industry's growth and lessen farmer poverty. When compared to the conventional immersion parboiling approach, the farmers at the Agriculture Business Centers (ABCs) do not use the improved steam parboiling method as frequently.

According to the data, there is a considerable difference between the parboiling techniques in the values obtained for drying losses. The milling yield figures for both processes also differ, but the difference is not statistically significant. When comparing the enhanced steam parboiling method to the conventional immersion parboiling method, the values from the grain quality criteria (head rice, fissuring, 1000 grain weight, chalky, and dockages) reveal a significant difference at the  $\alpha=0.05$  level of significance.

## **6. Conclusions and Recommendations**

### **6.1. Conclusion**

Reducing postharvest loss in rice presents a challenging issue for the majority of farmers in Sierra Leone. Obtaining information about existing postharvest losses proved equally difficult, as many farmers are aware of losses but struggle to quantify them. However, much was learned by using modern technology and the traditional method of parboiling, drying,

and milling rice at the various agriculture business centers (ABCs), as well as by conducting interviews about the nature and extent of postharvest loss in rice at the ABCs.

According to the survey results, interviewees also claimed that the lack of post-harvest equipment was the main issue causing the high post-harvest losses of rice. In addition to providing technical know-how and access to financial resources to obtain suitable supplies and machinery, rice farmers feel that mechanizing post-harvest activities can help minimize rice wastage.

The improved method (steam parboiling) of rice processing is not widely practiced in Sierra Leone. The method's distinguishing feature is that it yields better-tasting rice than traditional immersion-parboiled rice. From the results obtained,

- 1) The majority of the rice farmers - 70% and above-reported losses of at least 40% and above.
- 2) The percentage dry loss for the traditional immersion parboiling method (0.014) was greater than the improved steam parboiling method (0.004).
- 3) The milling yields for the traditional immersion parboiling method (70.91) and the improved steam parboiling method (72.0) do not show much significance.
- 4) The mean head grain rice yielded by steam parboiling was found to be significantly higher than the traditional immersion parboiling method's yield of 28.4% (20.2%).
- 5) The steam parboiling method takes more time (120 minutes) to steam than the traditional immersion parboiling method (65 minutes).
- 6) Fewer fissures (8.0%) were found in the improved method than in the traditional immersion parboiling method (27.8%).
- 7) The traditional immersion parboiling method has more dockages (6.0%) and chalkiness (22.0%) than the improved method (0.6%) and 9.6%, respectively.
- 8) The percent of 1000 grain weight for the steam parboiling method is so much greater (23.3%) than the traditional immersion parboiling method (17.2%).

## 6.2. Recommendations

The suggestions are divided into two (2) groups.

It focuses on socioeconomic advancement of farmers and scholarly debate. We advise the following suggestions:

It is well acknowledged that rice is a crucial cereal crop for feeding the global populace. Therefore, this research strongly supports initiatives for rice farmers to reduce postharvest losses through advocacy and education. The yield gap will be closed when a loss reduction program is combined with viable and sustainable food systems. This type of program should involve both farmer-based and community-based organizations in competitive rice production, proper timing of harvest, and farm field schools (FBOs). A tendency to save and turn rice losses into profits will result from the execution of a loss reduction scheme. This strategy will help rice growers understand postharvest losses more thoroughly. Programs like farmer field schools (FFS) and exchange visits

will connect farmers and extension staff when they are implemented in places where rice is grown. For instance, the current losses in the field will be reduced when rice farmers are instructed in loss reduction through demonstration fields.

Furthermore, these initiatives will raise awareness among rice farmers, business leaders, and top-level legislators. The scheme will then increase farmers' capacity to grow more rice, increasing the market's supply. For the purpose of the school feeding program, Sierra Leone's Ministry of Basic Education might be contacted through local sellers of rice or rice growers. In turn, this will help schoolchildren have access to food, offering up more market opportunities for farmers who don't meet international standards.

Farmers are aware of the lost rice, but they lack the means to address this problem. All potential fixes need for money, which is not available. To cut down on actual losses:

- 1) Better access to financing is necessary to acquire adequate equipment. With more money, farmers can invest in materials such as tarpaulins, containers, and machines.
- 2) Drying is another process that contributes to loss. Drying machines would significantly reduce these losses and keep animals away from the rice.
- 3) Farmers should be encouraged to use the steam parboiling method instead of the traditional immersion method to avoid or minimize losses in rice processing and improve grain quality.
- 4) Farmers must be trained in post-harvest loss and provided with appropriate measures to mitigate the loss during harvesting, processing, and storage.
- 5) Rice parboiling should be encouraged as a way of improving the cooking quality of rice.
- 6) Farmers and ABCs should be supplied with adequate milling machines that prevent breakages in grain.

Second, studies on loss assessment and reduction should be carried out in various rice-growing regions and agribusiness hubs that are involved in rice cultivation.

## Appendix



**Figure 10.** Traditional method of winnowing to remove empty grains; b. washing of paddy to remove unwanted materials (improved method).



**Figure 11.** Improved method of drying rice.



**Figure 12.** Steam parboiler; Improved parboiling pot.



**Figure 13.** Steam parboiler; Traditional parboiling pot.

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