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A NATIONAL SURVEY OF RICE (*ORYZA SATIVA* L.) GRAIN QUALITY IN SIERRA LEONE II: EVALUATION OF PHYSICAL GRAIN QUALITY

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ABSTRACT

Rice is a very important item of food and commerce in Sierra Leone and so information on the quality of available rice grains can serve as a useful indicator for the technical status and level of competitiveness in the local rice industry. During this study an objective evaluation was conducted to measure and characterize the quality of rice grains available in the local markets of Sierra Leone. A total of 315 randomly selected rice samples from 45 markets selected from the four major cities of Sierra Leone (Makeni, Bo, Kenema and Freetown, representing urban communities from the northern, southern, eastern and western parts of the country, respectively) were evaluated. Quality evaluation involved measurement of moisture content, number of paddy (unmilled rice kernels) in 1 kg of milled rice and other quality factors normally used for the grading of milled rice. Rice samples were then graded based on criteria adapted from the Philippines Rice Grading Standards for milled rice grains. The results showed that the quality of all grain samples evaluated was generally poor, with 63.2% of the samples failing to meet the criteria set for Grade III rice quality (meaning that the quality level was worse than grade III). Quality measures obtained for imported samples appeared to be superior to that obtained for the local samples in terms of higher proportions of superior grades (grade II or better). Comparison of measures of grading factors revealed that among the four cities considered in this study, grains from Kenema were of the lowest quality. Further examination of grade limiting factors revealed that the most critical factors responsible for poor quality outcomes in grain sample were (i) *the number of paddy in 1kg of milled rice* and (ii) *the moisture content* of grains. The study provided quantitative measures of the quality status of rice grains available in Sierra Leone, as well as a means of identifying the major *binding constraints* to rice grain quality, in terms of the grade limiting factors. It is speculated that the low quality of rice grains observed in this study could be the result of avoidable quality defects that may be linked to an undeveloped national system for rice milling and handling.

Key words: Rice grading, grain quality attributes, physical characteristics, Sierra Leone,

INTRODUCTION

Rice features prominently in the livelihood systems of Sierra Leone, both as a primary staple crop and as a central commodity for income generation in rural communities. Although per capita rice consumption in Sierra Leone is very high (about 104 kg per person per year), the domestic production of rice remains predominantly a smallholder subsistence farming activity [1]. Thus the national rice supply chain consists of numerous local sources and a small number of organized importers whose supplies make up a significant proportion of rice consumed in the country. Value addition opportunities for rice are also few, especially with respect to locally produced rice [2].Smallholder rice value addition consists mainly of manual harvesting, threshing, drying, milling, packaging, and storage operations by subsistence farming households using the most convenient methods at their disposal. These simple rice processing and handling practices normally come with important implications for postharvest losses and grain quality[3, 4, 5, 6, 7]. The predominant use of hand milling normally results in low milling and head rice yield recoveries and a high number of unmilled grains (also known as paddy or husk rice). Outdoor sun-drying also exposes grains to the risk to pest attack and contamination that might find their way to the market unchecked by a weak postharvest system.

The quality of rice grains can be viewed from many perspectives, including eating, cooking, storage, chemical, nutritional and physical perspectives, depending on the concept that best depicts its end use value [8, 9, 10]. With such multiplicity of perspectives, the meaning of grain quality for rice can easily become ambiguous. For the purpose of this article, the meaning of rice grain quality will be limited to its physical state as defined by physical quality factors. Common physical qualities used in grading milled rice include number of paddy (unmilled rice kernels) in 1 kg of milled rice, moisture content of grains and percentages of foreign matter, chalky immature grains, contrasting types and broken grains. In this respect, rice grain quality may be defined as the degree to which a given sample of grains meets a set of physical criteria set by an established and recognized grading system [11].

There are many rice grading systems serving as instruments of rice grain value measurement in the world of rice production and exchange[12]. The various Asian rice grading standards have many commonalities, even though they are based on different historical backgrounds and legal systems. For example, all grading standards are averse to moisture contents above 14 % (wet basis), damaged grains or grains with foreign matter and impurities while encouraging increased head rice yields and grain uniformity.

The recent shift in the demand for high quality rice, with increasing consumption of rice among more affluent societies, presents both opportunities and challenges to rice producers [11, 13]. As expectations of quality from the global market become more demanding, opportunities for local farmers in developing countries become reduced. A combination of weak rice production and post-production systems and a poor consumer base suggest basic technical limitations and poor market incentives for high quality rice

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[5, 6, 14]. As a major food item, the quality status of rice grains in Sierra Leone can provide evidence on the general nature of meal tables and level of competitiveness inherent in the local rice industry [13, 15].

In recent strides towards smallholder agricultural commercialization, in line with the Comprehensive Africa Agriculture Development Process (CAADP) and the National Sustainable Agricultural Development Plan (NSADP), emphasis is given to strengthening the rice postharvest system in Sierra Leone [2]. In this respect, Smallholder Commercialization Programme (SCP) targets the establishment of hundreds of community Agricultural Business Centres (ABCs) across the country to serve as rural processing facilities to support local food production and marketing systems through mechanization support for field and postharvest operations. Facilities at ABCs are mainly relevant to rice production and include small tractors, motorized threshers, communal drying floors, single- or two-stage rice mills, etc. These investments are expected to eventually translate to positive changes in the rice postharvest system. Information on the status of rice grain quality will provide the basis for determining the end-use benefits of these government interventions at the level of market interaction. In the first part of this article, issues around the quality interests of rice traders and consumers are presented [16]. To further examine the results in the study, a physical evaluation was conducted to measure and characterize the quality rice grains available in local markets across Sierra Leone and identify possible factors limiting the quality of rice products in Sierra Leone.

MATERIALS AND METHODS

Materials

A total of 315 randomly selected rice samples (approximately 450 to 500g), from traders in 45 markets located in four major cities of Sierra Leone, including 90 imported and 225 local rice products were collected for laboratory quality evaluation. The four cities, Makeni, Bo, Kenema and Freetown were selected to provide a national representation of urban Sierra Leone. With the exception of Freetown, the capital, where a total of 105 were collected from 15 markets located across the city, 70 grain samples were collected from 10 markets in each of the other three cities. Samples were collected in the month of June, 2010 and excluded supermarkets which offered a small collection of exotic rice products but were visited by a small number of upper class households.

Grain quality analyses

Quality analyses were conducted at the Department of Agricultural Engineering, Njala University, Njala Campus. Values of quality factors were determined in three (3) replicates as described in the following paragraphs used to determine the quality grade of individual samples based on modified grading standards of the Philippines (Table 1).

Number of paddy present in 1 kg of grain sample:

To determine the number of paddy present in each replicate, 100 gram samples were spread out on a white sheet of paper and manually picked out, counted and recorded.

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The number of paddy in 1 kg of milled rice was determined by multiplying this value by 10.

Percentage of foreign matter:
Twenty (20) gram samples of rice grains were weighed out in three replicates for determination of percent foreign matter. The grains were spread out on a white sheet and all foreign matter (including weed seeds, small stones, sand particles, pieces of metal, and other particles) were manually separated from the grains. The mass of foreign matter in the sample was determined using an analytic balance and expressed as a percentage of the original mass of the sample (Equation i).

$$\text{percent foreign matter} = \frac{\text{mass of foreign matter}}{\text{mass of sample}} \times 100\ \% \quad \ldots\ldots\ldots\ldots\ldots (\text{i})$$

Percentage of discoloured grains:
The percentage of discoloured grains involved the separation and weighing of all discoloured grains from the sample. The mass of discoloured grains was then expressed as percentages of the mass of the sample (Equation ii) to determine percent discoloured grain.

$$\text{percent discoloured grain} = \frac{\text{mass of discoloured grains}}{\text{mass of sample}} \times 100 \quad \ldots\ldots (\text{ii})$$

Percent damaged kernel:
All damaged grains were separated from the 20g sample using a pair of forceps and weighed. The percentage of damaged grains was determined by expressing the mass of damaged grains as a percentage of mass of sample analysed (Equation iii).

$$\text{percent damage grains} = \frac{\text{mass of damaged grains}}{\text{mass of sample}} \times 100 \quad \ldots (\text{iii})$$

Percent contrasting grains:
Contrasting rice grain types were manually separated from a20g sample and weighed. Percent contrasting type was determined by expressing the mass of contrasting grains as a percentage of the original weighed sample, as in Equation (iv) below:

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$$\text{percent contrasting grains} = \frac{\text{mass of contrasting grains}}{\text{mass of sample}} \times 100 \quad \ldots \text{(iv)}$$

Percent chalky:
Chalky and immature grains refer to rice grains that look like white chalk due either to incomplete or faulty starch crystallization which can be identified by visual inspection. Chalky and immature grains were separated from the sample (20g) and weighed. The percent chalky or immature grain was determined as the mass of chalky or immature grains expressed as a percentage of the mass of the original sample, as in Equation (v) below:

$$\text{percent chalky grains} = \frac{\text{mass of chalky grains}}{\text{mass of sample}} \times 100 \quad \ldots \text{(v)}$$

Moisture content:
Moisture content of rice grains was determined by the standard oven method. Five grams samples of rice grains (initial mass) were dried in a convective oven dryer (Fisher ISOTEMP® Oven 200 series) at 105^{o}C over 72 hours. After ascertaining constant mass, the final bone-dry mass was recorded (final mass). Moisture content was determined on percent wet weight basis using Equation vi.

$$\text{moisture content (\% w.b.)} = \frac{\text{initial mass} - \text{final mass}}{\text{initial mass}} \times 100 \ldots \text{(vi)}$$

Grading:
The values of grading factors determined from laboratory analyses were used to determine measures of quality for all samples using manual grading procedures. This involved obtaining values of all grading factors for each sample and comparing these values to the maximum limits allowable for all factors in each grade category, as defined by the grading standards (Table 1). A grade was then assigned to each sample on the basis of the ability of the sample to meet the criteria of maximum limits of all factors in the grade categories.

Data analyses:
Statistical analyses involved determination of grade frequencies and comparison of the mean values of grading factors using single factor analysis of variance with multiple variables (MANOVA) performed in SPSS16.0 and Microsoft Excel 2007 respectively.

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RESULTS

Grading outcomes

Figure 1 shows the distribution of grades assigned to rice grain samples collected from the cities of Bo, Freetown, Kenema, and Makeni. The data shows that 63.2% (n = 199 out of 315 samples) of all graded samples fell in a grading category inferior to grade III (Table 1). This category was not originally part of the grading system; it was created to accommodate samples which could not meet the limits set for grade III. Most of the other graded samples (22.2%, n=70 samples) fell into the category of grade III, with only 4.4, 7.9 and 2.2 per cent in grade II, grade I and premium grade, respectively.

Grading outcomes were separated into sources (cities) and types (imported or local) of rice. For instance, up to 75.7% (n=53 out of 70) of samples from Kenema City were in the category of grains worse than grade III; only 54.3% (n=57 out of 105) of samples from Freetown fell in this category. In addition, 1.4 % (n=1 out of 70) of samples from the other three cities fell in the premium category; up to 3.8% (n=4 out of 105) of samples from Freetown fell in the premium category. This suggests that, in this respect, the quality of rice available from Freetown may be better than that available in the other provincial cities. However, it was observed that samples from Bo and Makeni turned up with appreciable proportions of grade I samples (14.3 and 10.0%, respectively). In terms of the influence of rice grain types (that is, imported or local),the imported grain had a greater proportion of superior quality grades (Figure 1).

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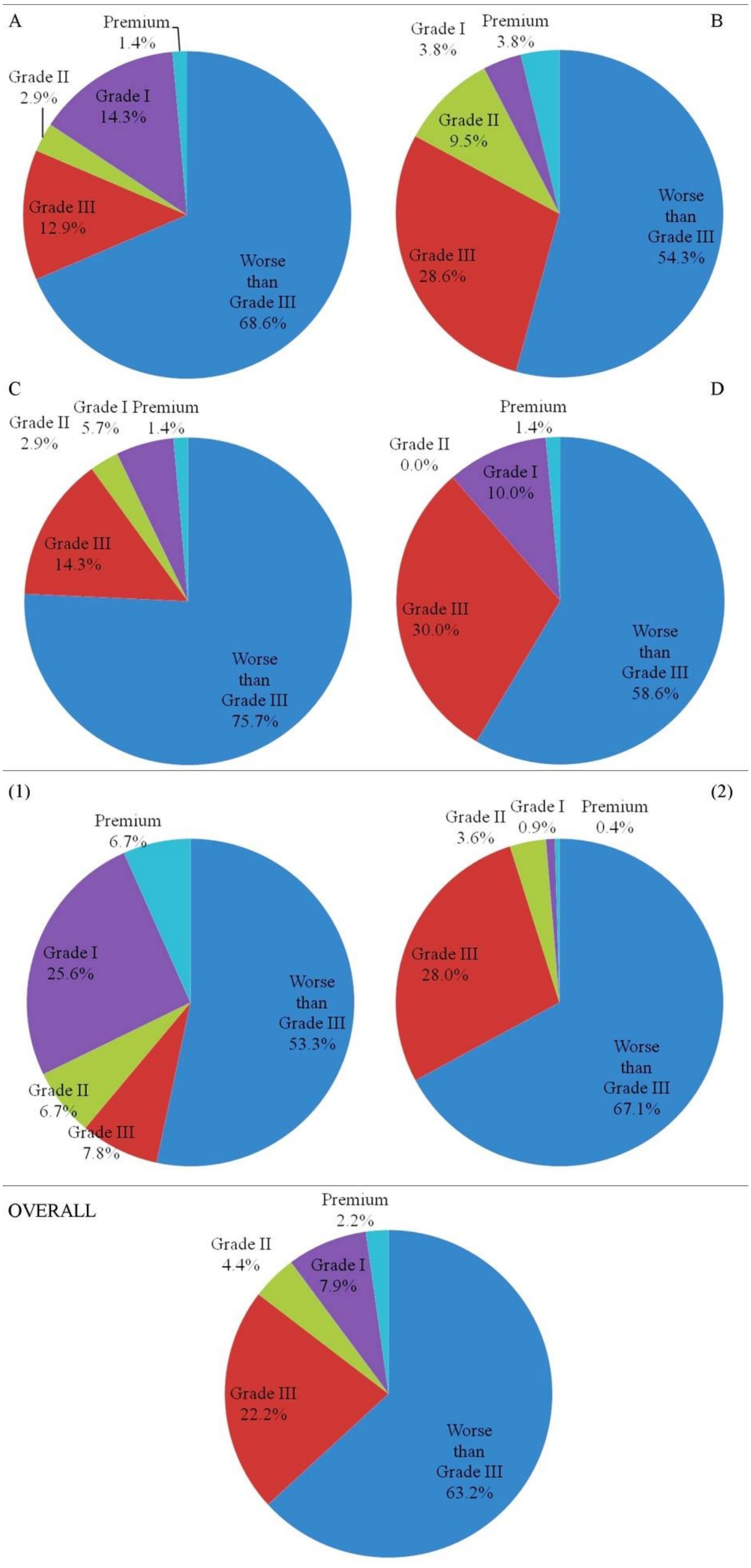

Figure 1:
Distribution of grades assigned to rice samples. Pie charts represent cities (A, Bo; B, Freetown; C, Kenema; D, Makeni)in Sierra Leone, grain type (1, imported; 2, local) and the overall survey (bottom).

Comparison of grading factors

The average values of individual grading factors obtained from different sources and types for rice were compared to determine variations (Table 2). The average moisture content ranged from 12.7% (Freetown) to 13.5 % (Kenema) and showed variation among cities. The average number of paddy (non-dehulled grains) in 1kg of milled rice samples ranged from 103 (Freetown) to 261 (Kenema) paddy grains per kg of milled rice grains. These values were significantly different among cities as well as between grain types. However, the range of values obtained for the average number paddy per kg was far beyond the acceptable limit for grade III (Table 1).

Grade limiting factors

During the process of grading, measured factors were compared to the limits set by the grading standard for each category, starting from premium to grade III (Table 1). A grade is chosen after all measures have been compared to their limits for premium, grade I, grade II or grade III and all factors are found to meet the condition for that grade. The factor whose measure exceeded the limit for the last grade category tested, and into which the batch or sample falls, is considered the grade limiting factor.

Grade limiting factors were recorded for all rice grain samples evaluated and their frequencies of occurrence tallied. Table 3 shows the frequency distribution of graded samples by the various grade limiting factors. Only 7 flawless or non-defective samples (that is, samples without a limiting quality factor) were identified. These fell in the category of premium rice. The data show, in order of magnitude, that the most important grade limiting factors were *number of paddy in 1kg of milled rice*, *percent damaged kernels*, *percent foreign matter* and grain *moisture content*. In fact, *the number of paddy in 1kg of milled rice* and grain *moisture content* were the critical factors responsible for most of the rice samples falling in the grade category worse than grade III. Samples in grade III were mostly limited by percent foreign matter and percent damaged kernels. The percentage of chalky or immature grains was not a grade limiting factor for any of the samples evaluated. Thus, the failures in rice grain quality observed in this study were mainly linked to poor milling, which results in a large number of paddy in 1kg of milled grains; and improper handling operations, which result in high percentages of damaged kernels, foreign matter and grain moisture.

DISCUSSION

The quality of rice grains in the market is determined by various factors in a given value chain [9]. Among these, the roles farmers, processors, transporters and retailers play are very critical in defining the status of grains which consumers access. Although appropriate coordination and linkages among postharvest actors will normally have compensatory benefits, there is a limit to how far downstream activities can compensate for earlier failures especially at the production level. Rice mills are central to rice grain quality [9, 17]. Poor milling facilities could be responsible for the low quality outcomes encountered with local rice products in this study. This is consistent with results presented in the first part of this article, suggesting greater preference by

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both traders and consumers for imported rice products [16]. Perhaps the greatest challenges for grain quality in Sierra Leone are likely to be at the levels of field production and processing, due to the predomination of subsistence practice at these levels [2]. For instance, traditional harvesting and handling practices naturally predispose grains to poor quality. During such practices rice stalks are cut in bulk, sometimes along with weed plants and left in the field for several days to weeks to cure. During field curing, threshing and drying the grains may be further exposed to insect, bird and rodent pests. In most cases the grains may also be left unprotected from dirt and moisture, leading to varying degrees of quantitative and qualitative postharvest losses. Also, improper hand threshing with sticks and uncontrolled sun-drying can lead to grain fissuring and additional contamination. Traditional hand milling, using wooden mortar, pestle and winnowing fans, offers limited opportunity for correcting most of these quality problems. The quality of most local rice products are likely to be restricted by these conditions. Unlike locally produced rice, almost all imported rice entering Sierra Leone comes from Asia [1, 18], and are supplied by large scale rice processors with superior rice milling systems [7, 12 17]. These superior rice mills are specifically designed to enhance grain quality and normally consist of multistage processing machinery with separate system components for drying, cleaning, milling, sorting and bagging.

Despite an apparent inferiority in physical quality of domestically produced rice, there is evidence suggesting the existence of cross border rice trade between Sierra Leone and Guinea [19, 20]. Cross-border trade could have been sustained by dual benefits of trade, the need for convenience, smuggling activities and family ties. Incidentally, this trade provides '*visibility'* for rice from Sierra Leone while depicting a potential for further penetration into the regional market if products are made more competitive.

The study suggests that the most important grade limiting factors are number of paddy in 1kg of milled rice and moisture content (Table 3). Defects in moisture content could be ascribed to poor handing at every stage (including the handling of samples collected for this work). Grading failures due to excess paddy in milled grains were caused by poor rice milling operations. A distinction was made between imported and local rice samples with respect to quality limitations due to this factor. Majority of farmers in Sierra Leone mill their rice grains by hand, pounding using wooden mortars and pestles with hand-woven winnowing fans [18]. It is usual for farmers to consider milling operation to be complete while there is still a substantial amount of paddy in the batch. Hand picking done to remove these unmilled grains is considered to be part of the household meal preparation chores. Grading failures due to moisture defects point to the poor storability of the grains since rice grains with moisture content in excess of 14 % (wet basis) will normally show poor storage quality [21].

The four cities selected in the study represent the four cardinal regions of the country (Kenema representing the Eastern Province, Bo representing the Southern Province, Makeni representing the Northern Province and Freetown representing the Western Area). As the capital city, Freetown is expected to attract rice products from all parts of the country while the other three cities are expected to attract rice from producers in the respective regions. Apparent differences in grading outcomes and measures of grading factors might represent actual variations in the relative efficiencies of the local rice postharvest systems in these regions (Figure 1). Bo (18.6%) and Freetown (17.1%) turned up with better quality rice grains than Makeni (11.4%) and Kenema (10.0%), in terms of the proportion of Premium (Grade I + Grade II) rice. This trend was maintained with the mean values obtained for grading factors, with samples from Freetown or Bo, which had the best mean values (Table 2). Samples from Kenema came up with the worst scores in all quality factors examined compared to samples obtained from other cities. This is perhaps evidence of a relatively more degraded postharvest system in the eastern parts of the country. The recent civil unrest in Sierra Leone(1991 – 2002), which hit a heavy toll on the country's agricultural economy, could have contributed to the degradation of the rice harvesting system of the country [22]. Communities located in the eastern region of the country were the hardest hit during the war. These communities suffered from both the loss of productive assets as well as human capital associated with insurgent activities [23, 24].

Careful reorganization of the rice value chains across Sierra Leone will be essential for the attainment of the dual national development goals of food security and agricultural commercialization. Identifying some of the key quality limiting factors is very helpful, but only to a point. It might be helpful to note that each major grade limiting constraint must be recognized as *binding constraints* limiting the attainable quality. Close attention to these factors and making them the basis for formulating specific postharvest interventions could result in more accurately removing the barriers to rice grain quality in Sierra Leone. Thus, rice mills hold the key to improving the quality of rice grains in Sierra Leone [24]. With the recent introduction of ABCs, equipped with small rice milling facilities, the quality of local rice products are expected to improve. Increased involvement of efficient specialized millers in rice processing will potentially upgrade the quality of the national rice production system [7]. This is an essential step in order to ensure entry and survival of rice farmers in highly competitive regional and international markets. However, in the present economic structure, consisting of many poor households with large household sizes, premium rice grains offered will come at a price that might be out of the reach of the common household [16]. In the interest of affordability and access, the introduction of ABCs appears to be the best approach at this point in time. All ABCs use small one- and two-stage milling systems, which have inherent technical limitations with respect to their quality enhancement capabilities. Ideally, meeting the excellent quality levels required by the global rice market on a routine basis requires the capabilities of large rice mills. However, recent history indicates that liberalization of the rice sub-sector was as a result of small mills outcompeting larger, inefficiently run large mills [3]. Thus, if their operations are properly organized to optimize commercial interests, existing single- or two-stage rice mills can make important contributions to the rice subsector.

CONCLUSION

As the primary national staple and the most important product of rural economic activities in Sierra Leone, rice production and marketing is central to national development. The issue of rice grain quality is an important piece in the national pursuit of food security and a market driven agricultural system due to its link to sustainable processing, handling, marketing and rural livelihoods. Results obtained from both grain quality measurements and grading analysis conducted on the basis of physical grain properties indicate that the quality of milled rice available in Sierra Leone is generally poor. The data further suggests that the quality of imported grains from all four cities was far superior to that of the local grains. The quality of rice from Freetown appeared to be better than those from the other cities, especially those originating from Kenema, which had the worst quality measures in all respects (*number of paddy in 1kg of milled rice*, *percent damaged kernels*, *percent foreign matter* and *moisture content*). The study provided a means of identifying the major *binding constraints* to rice grain quality in terms of the grade limiting factors. These results lead to the conclusion that the apparent poor quality of rice grains in the country is the result of avoidable quality defects, which may be linked to poor rice milling and handling practices in the country.

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Table 1: Grading factors* used for the classification of rice grain samples [12].

Grading Factor	Premium	Grade I	Grade II	Grade III	Worse than Grade III
Moisture Content (% w.b.)	14.00	14.00	14.00	14.00	> 14.00
No. of paddy in 1kg of grain sample	1.00	8.00	10.00	15.00	>15.00
% Contrasting type	3.00	6.00	10.00	18.00	>18.00
% Chalky and immature grains	2.00	5.00	10.00	15.00	>15.00
% Discoloured grains	0.50	2.00	4.00	8.00	>8.00
% Foreign matter	<0.10	0.10	0.20	0.50	>0.50
% Damaged kernels	<0.25	0.25	0.50	2.00	>2.00

**This is an adaptation of the rice grading standards of the Philippines presented in the article cited and has been modified to suit the objectives of the present study.*

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Table 2: Mean values of grading factors determined for rice grain samples collected from 4 cities in Sierra Leone (±standard error of mean)*

Source / type of rice	Moisture content (% wet basis)	Number of paddy in 1kg of milled rice	Percent contrasting type	Percent immature or chalky grains	Percent discoloured grain	Percent foreign matter	Percent damaged kernel
Source:							
Bo	13.05±0.13[a,b]	192±27[b]	0.28±0.01[a]	0.28±0.01[a]	0.81±0.07[a]	1.52±0.25[a]	3.85±.33[b]
Freetown	12.72±0.12[a]	103±19[a]	0.26±0.01[a]	0.25±0.01[a]	1.03±0.13[a]	2.72±1.93[a]	1.52±0.17[a]
Kenema	13.52±0.19[b]	261±32[c]	4.36±0.51[b]	1.71±0.35[b]	1.24±0.17[b]	4.78±2.20[b]	4.53±0.32[c]
Makeni	13.17±0.20[a,b]	135±24[a,b]	0.27±0.01[a]	0.27±0.01[a]	0.89±0.10[a]	0.43±0.09[a]	4.13±0.42[b,c]
Type:							
Imported	13.06±0.13[a]	24±3[a]	0.28±0.09[a]	0.20±0.02[a]	0.49±0.04[a]	0.12±0.04[a]	0.90±0.17[a]
Local	13.06±0.10[a]	221±16[b]	1.53±0.20[b]	0.74±0.12[b]	1.20±0.08[b]	3.32±1.13[b]	4.24±0.19[b]
Overall:	13.06±0.08	165±13	1.18±0.15	0.59±0.08	0.99±0.06	2.40±0.81	3.29±0.17

*For each set (that is, source or type), means in the same column (factor) bearing the same superscript are not significantly different.

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Table 3: Distribution of graded samples by the grades assigned to them and grade limiting factors

Limiting Quality Factor	Type of Rice	Grade Assigned					All grades
		Worse than grade III	Grade III	Grade II	Grade I	Premium Grade	
Flawless	Imported	0	0	0	0	6	
	Local	0	0	0	0	1	
	Total	***0***	***0***	***0***	***0***	***7***	***7***
Moisture Content	Imported	12	0	0	0	0	
	Local	13	0	0	0	0	
	Total	***25***	***0***	***0***	***0***	***0***	***25***
Number of Paddy in 1 kg of grains	Imported	36	1	0	2	0	
	Local	137	0	0	0	0	
	Total	***173***	***1***	***0***	***2***	***0***	***176***
Percent Contrasting Types	Imported	0	0	1	0	0	
	Local	0	1	0	0	0	
	Total	***0***	***1***	***1***	***0***	***7***	***2***
Percent Chalky and Immature Grains	Imported	0	0	0	0	0	
	Local	0	0	0	0	0	
	Total	***0***	***0***	***0***	***0***	***0***	***0***
Percent Discoloured Grains	Imported	0	0	2	7	0	
	Local	0	2	0	1	0	
	Total	***0***	***2***	***2***	***8***	***0***	***12***
Percent Foreign Matter	Imported	0	0	0	1	0	
	Local	1	26	2	1	0	

Limiting Quality Factor	Type of Rice	Grade Assigned					All grades
	Total	***1***	***26***	***2***	***2***	***0***	***31***
Percent Damaged Kernels	Imported	0	6	3	13	0	
	Local	0	34	6	0	0	
	Total	***0***	***40***	***9***	***13***	***0***	***62***

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