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Physical quality and safety assessment of selected varieties of local paddy and milled rice processed by cottage rice mills in Uganda

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Abstract

The urban and peri-urban population provide niche markets for rice in Uganda. The local rice industry, dominated by smallholder farmers and cottage mills has failed to meet quality requirements of quality-sensitive consumers. Due to lack of information on physical quality and safety of the locally grown and processed rice, informed decision making on investments in the sector has been compromised. Using standard analytical and physical methods, local paddy and milled rice main varieties (*NERICA 4, Kaiso* and *Supa*) sampled from all major rice growing districts of Uganda were assessed for quality and safety. The results showed that paddy supplied to rice millers exhibited low quality characteristics exemplified by fissure levels of 60%, foreign matter of 6.1%, moisture content of 10.6% and aflatoxin contamination of 18 pbb. Similarly, milled rice obtained from different parts of the country and processed by cottage mills exhibited low market value namely; aflatoxin up to 19.5 ppb, 64.3% broken grain, 0.8% foreign matter and 0.06% rancidity. Although rice available on the market was fairly safe for consumption, the physical quality which determines the price tag required urgent improvement. Hence the need for measures to improve post-harvest handling and processing technologies for smallholder farmers and cottage mills.

Key words: Extraneous matter, fissure, rancidity and aflatoxin, rice varieties, Uganda

Introduction

In the recent past, rice has gained a lot of economic importance in Uganda. It has a comparative market advantage and 1.83 rate of return (NAADS, 2004) over other crops especially cereals. The Ministry of Agriculture Animal Industry and Fisheries (MAAIF) estimated that the national demand for rice in the year 2010 was 240,000 metric tons and the deficit was 49,920 metric tons which was bridged by importation (MAAIF, 2010). The local rice industry is faced with several challenges which include low physical quality, unacceptable safety and market value which in turn makes the local rice less competitive in market place, among others. Besides, the potential consumers in urban and peri-urban centres have become increasingly sensitive to food safety issues (REF). Studies in mid-northern Uganda showed that maximum aflatoxin level contamination in the paddy was 31 ppb while the average was 10 ppb (Candia *et al.*, 2010b). Though the average value was below the allowable 20pbb FAO recommended limit for human food and animal feed, the maximum level was well above the recommended value (Kaaya and Warren, 2005). Based on the European Union (EU) standard of 4ppb for adult food and 0ppb for baby foods, none of the rice types in Uganda can be traded in the EU market (FAO, 2004) due to unacceptable level of contamination.

In Uganda, an estimated 80% of the local paddy is produced by smallholder farmers who use rudimentary and inefficient practices and technologies for carrying out production and post-production rice farming operations (Candia *et al*, 2008). The smallholder rice farmers also have inadequate knowledge in post-harvest handling and processing of rice (Odogola, 2006). A combination of these two factors has resulted into supply of low quality paddy to the rice milling factories by farmers. Similarly, most of the paddy in the country is processed by cottage milling companies who use improved engleberg and mill-top type of rice mills. By current standards, they represent outdated designs. This type of rice mill usually causes high broken grain and do not clean the milled rice adequately. The net effect of these factors is that the locally grown rice by smallholder farmers and processed by cottage rice milling companies does not compete well with imported brands in the liberalized market economy of Uganda . In view of the prevailing circumstances, the present study was to assess the physical quality and safety status of the local paddy and milled rice in Ugandan small towns and rural settings as a prelude for development of appropriate technologies. It is in these places that entire local rice in Uganda is grown and processed for marketing mainly in major urban and peri-urban. The generated information would then influence national policy formulation and contribute to investment decision- making in rice industry.

Materials and methods

Sample size and varieties used in the study

Samples of paddy and milled rice were collected from the four main rice growing regions of Uganda. The three major rice varieties grown in the country namely *NERICA 4*, *Kaiso* and *Supa* were targeted for the study. *NERICA 4* is the main rice variety grown in the central and western regions of the country while *Kaiso* and *Supa* are grown in eastern region. The northern region grows all the three rice varieties. Samples of *NERICA 4* were collected from central and western regions, *Kaiso* samples were collected mainly from the eastern region and *Supa* samples were collected from the north. A total of 20 samples of paddy each weighing 5 kg were collected from 20 rice milling companies in Lira (5 samples), Butaleja (5 samples), Nakaseke (5 samples) and Hoima (5 samples). The paddy was supplied by 20 different randomly picked smallholder farmers. Similar to paddy, a total of 16 samples of milled rice each weighing 5 kg were collected from 16 cottage rice milling companies. Of these Lira had 4 samples of *Supa* variety, Butaleja had 4 samples of *Kaiso* variety, Nakaseke and Hoima each had 4 samples of *NERICA* 4. The milled rice was collected from 16 of the same rice mills where paddy was collected. To understand the relationship between paddy quality supplied and quality of milled rice by the same company, these samples were labelled and primary variables obtained were presented as corresponding data.

Experimental design

Fissure levels, foreign matter, moisture content, aflatoxin and rancidity were the primary variables used to assess the physical quality and safety of paddy supplied to mills by smallholder farmers. Foreign matter, whole grain and broken grain in the milled rice were the primary variables used to assess the physical quality of the locally milled rice by the cottage rice milling factories. Standard analytical methods were used to assess aflatoxin and rancidity development in the same samples. Since each of the major rice variety (*NERICA 4, Supa* and *Kaiso*) was not grown in all the four regions, variety was kept as one of the covariates in this study. The term foreign matter in this study meant any unwanted material either in the paddy or the milled rice. The experimental designs used were as follows:

a) A 4x5 CRD comprising 4 locations (Buteleja, Hoima, Nakaseke and Lira districts in the eastern, western, central and northern regions respectively) and five farms in each of the four locations. This design was used to assess the quality of paddy supplied by smallholder farmers to millers
b) A 4x4 CRD consisting of 4 locations (Buteleja, Hoima, Nakaseke and Lira districts) and four cottage rice milling companies in each of the four locations. This design was used to assess the quality of milled rice processed by cottage rice milling companies.
c) Regression was used to determine the relationship between level of broken grain and fissure level in paddy as well as relationship between level of broken grain and moisture content of paddy.

Determination of evaluation parameters

1) Determination of fissure level

Fissure analyser, locally made by Agricultural Engineering and Appropriate Technology Research Centre (AEATREC), was used to determine fissure levels. Internationally, grain count of 100 is used in estimating fissure level. To increase data validity the research team opted for a bigger population size and consequently used a grain count of 216 in the analysis of each of the 20 samples collected. For each main sample, 216 well developed grains were randomly handpicked and their husks removed by hand. The fissure analyser used had a capacity of 36 grains. The brown rice grains obtained were then divided into 6 samples and each sample was placed in the fissure analyser. The grains that had fissures were observed, counted and expressed as a percentage of 36 grains. This process was repeated for the remaining 5 samples. The average fissure level in that main sample was then obtained using fissure levels in the 6 small samples. The process was then repeated for the samples collected from the rest of the rice mills.

2) Determination of foreign matter, whole grain and broken grains

From each of the main samples collected from rice mills, four different samples each weighing 300g were subjected to assessment of foreign matter contamination that consisted of mainly stones, soil, straws and weeds. Each type of contaminant was removed from the sample by hand. The weight of the foreign matter removed was obtained using a mechanical triple beam balance which had three graduated beams and 2, 610 g capacity, made by OHAUS. The weights obtained were expressed as a percentage of the sample weight. This process was repeated for the other three remaining samples and their average obtained to give the foreign matter contamination of paddy and milled rice collected from that rice milling factory. The same method was used to determine the levels of whole grain and broken grain.

3) Determination of moisture content in paddy

Electronic hand moisture meter model Riceter m 401 made by Kett-electric Company in Japan was used to determine moisture content of all the 20 paddy samples collected. From each of these main samples, four different samples were made to determine moisture content. Average moisture content from the four sub-samples was calculated to give the moisture content of paddy from that rice milling plant.

4) Determination of aflatoxin contamination

The aflatest quick fluorometer procedure for grain (0.2 gram sample equivalent) was used to test for aflatoxins using AflaTest® Fluorometer (VICAM L. P, USA) in the collected samples of paddy and milled rice. The detection limits were set at 0 parts per billion (ppb) (lowest) and 200 ppb (highest). The grains were ground using the Waring Blender with stainless steel container (VICAM Product No. 20202, USA). From each grain sample, 50 g of grain flour were weighed, mixed with 5 g of sodium chloride and placed in the blender jar. Methanol: water solution (80:20, v/v), was added to the flour and blended at high speed for one minute. The blended mixture was filtered using a fluted filter paper and the filtrate collected in a clean vessel. Ten millilitres of filtrate was pipetted into a clean vessel and diluted with 40 ml of distilled water, mixed thoroughly and filtered through glass microfibre into a clean glass syringe. From the syringe, two millilitres of the filtered dilute extract (2 ml = 0.2g sample equivalent) was passed through Aflatest-P affinity column at a rate of 1-2 drops per second and the column rinsed with distilled water. The affinity column was eluted by passing 1ml HPLC grade methanol through the column at a rate of 1-2 drops per second, and the eluate collected in a glass cuvette. A 1.0 ml of Aflatest developer solution was added to the eluate, mixed thoroughly and the cuvette was placed in the AflaTest fluorometer earlier calibrated to read total aflatoxin. Aflatoxin levels (ppb) in the samples were detected and recorded after 60 seconds. The range and mean levels were computed.

5) Determination of rancidity level

The rate of oleic acid break down into free fatty acid was used as an index for rancidity level in paddy. Diethyl ether and ethanol were mixed in a ratio of 1:1, in presence of 1 ml of 0.5% phenolphalein indicator in every 100 ml of the mixture. The mixture was carefully neutralized with 0.1 M sodium hydroxide. About 5 g of the ground paddy sample was accurately weighed out into a clean conical flask, 50 ml of the above mixture added, stopper fitted, flask shook and allowed to stand for 10 minutes. All the 50 ml extract (supernatant) was carefully decanted into another clean conical flask and titrated using standard sodium hydroxide solution of 0.1M. From the titre obtained the free fatty was calculated and reported as oleic acid using equations (1), (2) and (3) below.

Let:

Weight of the sample = W
Volume of Titre 0.1M NaOH = V
Volume of sample n (replicate n) = V_n

It is known that 1.0ml of 0.1M NaOH = 0.0282 g oleic acid.

Then weight of oleic acid in W_1 of the sample 1 (replicate 1) = $0.0282 \times V_1$ .... (1)

The weight of oleic acid in 1 g sample = $(0.0282 \times V_1)/ W_1$ .... (2)

Then weight of oleic acid in 100 g sample = $(0.0282 \times V \times 100)/ W_1$ .... (3)

Data analysis

ANOVA was used to compare the means of fissure levels, foreign matter, moisture content, aflatoxin and rancidity across the four districts. Regression analysis was used to observe the relationship between level of broken grain and fissure level in the paddy and also broken grain and moisture content of paddy. Fissure levels, foreign matter, moisture content, aflatoxin and rancidity were also estimated.

Results

Paddy quality parameters

The assessment of physical quality aspects of paddy focussed on foreign matter level, moisture content and the fissure level. The level of foreign matter contamination significantly varied with four regions (P = 0.000025). The highest levels of foreign matter was observed in paddy samples obtained from Hoima and Nakaseke districts which stood at 5.9% and 6.1% respectively (Figure 1), while the values of foreign matter from Lira and Butaleja districts were 2.8% and 2.3% respectively. Field observations showed that the foreign matter consisted mainly of stones, dust and straws. Similarly the fissure levels in the paddy were generally

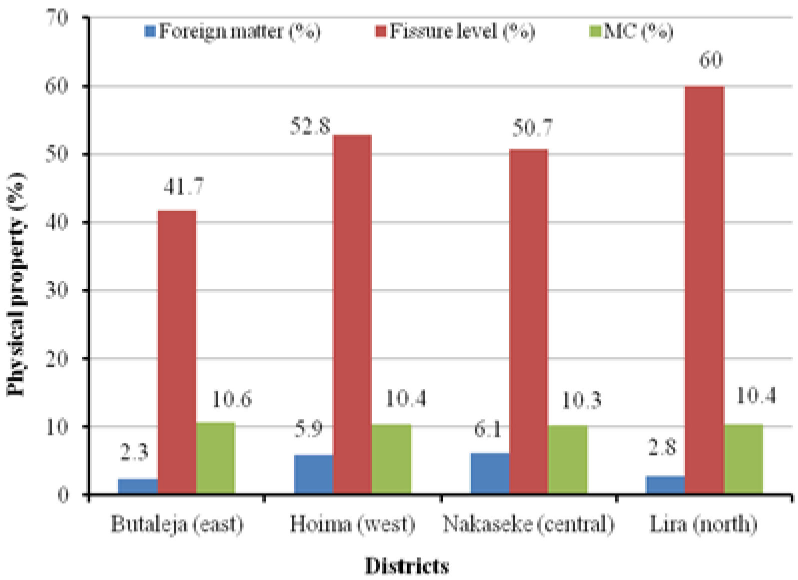

Figure 1. Variations in average physical properties of paddy across the region.

very high. Lira district had the highest fissure level at 60.0% while Hoima and Nakaseke districts had the medium fissure levels at 52.8% and 50.7%, respectively and Butaleja District had the lowest fissure level at 41.7% (Figure 1). However, there were no significant variations of fissure levels observed in the paddy from the four regions (P = 0.512). The results also showed that the moisture content of the paddy did not vary with regions (P = 0.951) which implied uniformity of drying practices across the board. Indeed, all farmers dried their paddy beyond the recommended milling and storage value of 13 -14% (w/b) (MAFFJ, 1995).

Aflatoxin and rancidity were the only safety factors assessed in paddy from the four regions. There were significant variations of aflatoxin levels of samples collected from Lira (north) district with those from other districts (P = 0.000462). The highest aflatoxin level 18 ppb was recorded in samples from Lira district and lowest 9.78 ppb was shown by the samples from Nakaseke district (Table 1). Samples from Butaleja and Lira districts had the same value of rancidity 0.03% (Table 1). Supa variety had the highest value 18 ppb of aflatoxin (Table 2) among the most grown local rice varieties. However, there were significant variations in rancidity levels across the four regions (P = 0.0005). The rancidity development was measured as percentage of Free Fatty Acidy (FFA) pertaining to Oleic acid.

Milled rice quality parameters

The physical quality of milled rice was assessed in terms of broken grain, whole grain and foreign matter. The results indicated that the highest broken grain level of 64.3% was observed in *Supa* variety obtained from Lira district and the lowest level (52.7%) was observed in *Kaiso* variety obtained from Butaleja district (Figure 2). The level of broken grain in samples of *NERICA 4* obtained from Hoima and Nakaseke districts were 56.8% and 54.9% respectively. There were no significant variations in the level of broken grain across the four regions (P = 0.494). This had influence on the level of whole grain which did not vary across the board (P = 0.78). The highest level of foreign matter (0.8%) was observed in Nakaseke

Table 2. Variations in average aflatoxin levels in paddy of commonly grown rice varieties

Variety	Aflatoxin (ppb)
Kaiso	11.46
NERICA 4	12.25
Supa	18.25

Table 1. Regional variations in aflatoxin and rancidity levels in paddy

District	Aflatoxin (pbb)	FFA % Oleic acid
Butaleja (eastern region)	10.08	0.03
Hoima (western region)	12.25	0.01
Nakaseke (central region)	9.78	0.01
Lira (northern region)	18.00	0.03
P-value	0.000462	0.0005

and Hoima districts while the lowest level (0.1%) was observed in both Lira and Butaleja districts. There were significant variations in levels of foreign matter across the four regions (P = 0.00085).The foreign matter in this study consisted of stones, paddy, straws and any other matter apart from milled rice.

Regression analysis was carried out to determine the relation between the levels of total broken grain in the milled rice and fissure level in paddy from each district. The analysis showed that there is a positive linear relationship between level of broken grain in milled rice and fissure level in paddy (R^2 = 0.862)

There were variations in the aflatoxin contamination in milled rice of the obtained samples (P = 0.00124). The average aflatoxin level in samples collected from Lira district was exceptionally high at 19.4ppb (Table 3). Samples from

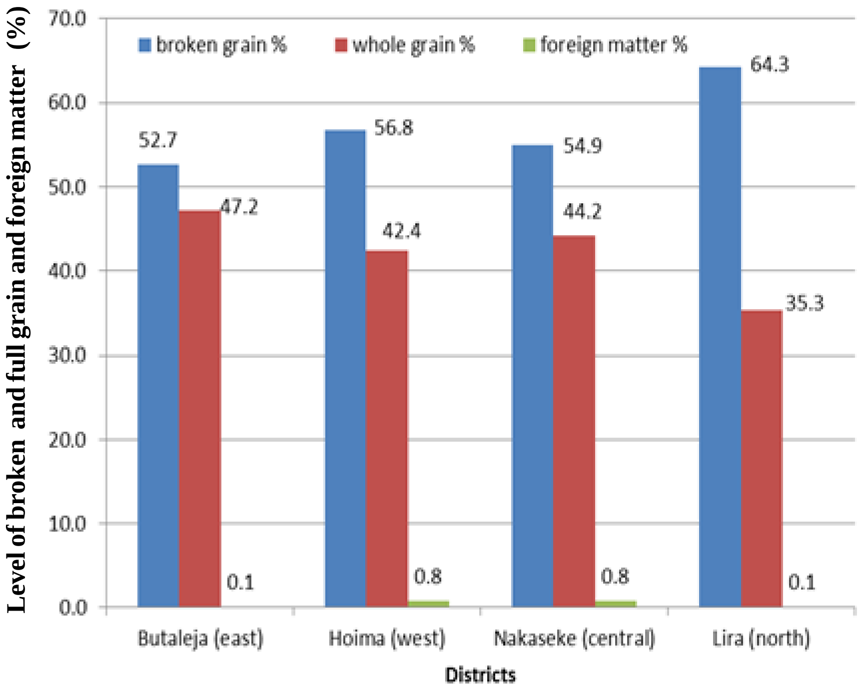

Figure 2. Average levels of broken grain, whole grain and foreign matter in milled rice.

Table 3. Variations in average aflatoxin and rancidity levels in milled rice across the region

District	Aflatoxin (pbb)	FFA % Oleic acid
Butaleja (eastern region)	11.0	0.03
Hoima (western region)	10.4	0.01
Nakaseke (central region)	9.6	0.06
Lira (northern region)	19.4	0.02
National average	12.6	0.03
P value	0.00124	

Nakaseke district showed the highest level of rancidity.

Discussion

Physical aspects of paddy quality

The presence of stones, straws and other forms of physical contaminants in paddy are known to contribute to damage of milling machines (MAFFJ, 1995). They were high levels of foreign matter in paddy from Hoima (west region) and Nakaseke (central region) districts which were 5.9% and 6.1%, respectively. Since these farmers use the same post-harvest practices and technologies, the disparity in these values could be attributed to experience. Farmers in east and north were more experienced in handling and marketing of paddy than farmers from the other regions. Fissure levels observed in the paddy from the all four regions were very high. As there is lack of internationally recognised or recommended standard, experience shows that maximum fissure level in the paddy of the local varieties should not exceed 20%. Paddy with high fissure level usually results into low mill recovery and high percentage of broken grain (up to 70%) which ultimately reduces market value of the milled rice. Farmers dried their paddy beyond the recommended milling and storage value of 13 -14% (w/b) (MAFFJ, 1995). When the paddy is over dried, the level of broken grain increases and contributes to low mill recovery. The practice of traditional methods and technologies by smallholder farmers for carrying out various post-harvest operations may have also contributed significantly to the poor physical quality of the paddy.

Physical aspects of quality of milled rice

The highest broken grain level of 64.3% (Figure 2) was observed in *Supa* variety obtained from Lira district and the lowest level (52.7%) was observed in *Kaiso* variety obtained from Butaleja district. The rice millers in the two districts from which the samples were collected used improved engleberg N-series type of rice mills. The variation in these levels of broken grain could be attributed to two main factors. First is the varietal difference of Supa and Kaiso. The second aspect is the combination of poor post-harvest handling of the paddy and weather differences in which paddy from the two places was dried. The rice in Lira was harvested from September to November which is generally hotter than Butaleja. The paddy in Lira district could have therefore, been dried at a faster rate than that in Butaleja district. The faster the rate of drying, the higher fissure level thus resulting into high level of broken grain (MAFFJ, 1995). The level of broken grain in samples of NERICA 4 variety obtained from Hoima and Nakaseke districts were 56.8% and 54.9% respectively, and the difference between the two is negligible. During collection of samples, it was observed that paddy from which the milled samples were purchased were all *NERICA* 4 which had been mixed with other varieties. The entire paddy milled in Lake Albert region (where Hoima is located) and central region were mixed batches of NERICA 4 and other upland rice varieties. Physiologically, each variety has its own strength and hence different milling pressures. It is therefore, difficult to mill paddy that has more than one variety. In an effort to eliminate or reduce the level of paddy coming into the milled rice, the weaker variety gets crushed into fragments. This phenomenon contributes to high level of broken grain in milled rice.

A positive linear relationship was observed between fissure level in paddy and level of broken grain in milled rice (Figure 3). The level of broken grain appears to be significantly increasing with the increase in fissure level in the paddy (R^2 = 0.862). This therefore shows that fissure in the paddy is one of the factors that cause broken grain in milled rice. Figures 1 and 2 show that the highest and lowest fissure levels were observed in samples obtained from Lira and Butaleja districts respectively. Similarly, the highest and lowest levels of broken grain in milled rice were also observed in Lira and Butaleja districts respectively. The result of regression analysis also showed that drying paddy of *Kaiso*, *Supa* and *NERICA 4* varieties to moisture of 10 – 11% (w/b) did not have much effect on level of broken grain (R^2 = 0.123).

Presence of foreign matter, especially stones lowers the market value of milled rice. The highest level of foreign matter (0.8%) was observed in Nakaseke and Hoima districts while the lowest level (0.1%) was observed in both Lira and Butaleja districts. This correlated well with the level of foreign matter observed in the paddy. Hoima and Nakaseke districts had the highest level of foreign matter in their paddy than the other two districts. The cottage rice milling factories use rudimentary milling practices and improved engleberg/mill-top types of rice mills in their processing lines. These types of mills are out dated designs and usually, cause high level of broken grains (MAFFJ, 1995). Without any other equipment for paddy cleaning, de-stoning and grading of milled rice, it is very difficult for these millers to remove all the foreign matter from the milled rice. Similarly, these mills also contribute to high level of broken grains.

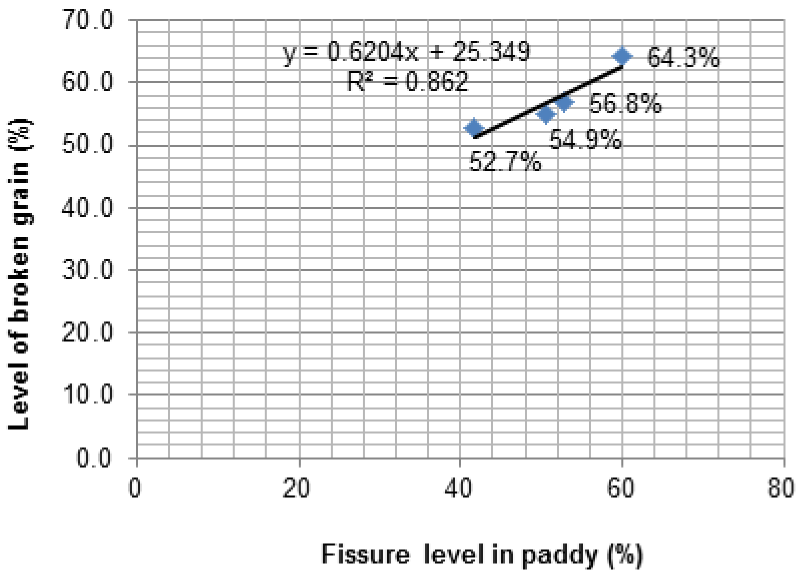

Figure 3. Correlation of levels of fissure in paddy and broken grain in milled rice.

Safety aspects of paddy and locally milled rice

Food safety is a fundamental right of every consumer. As such, safety standards have been set to guarantee the health of consumers. With regard to aflatoxin, the Food and Agricultural Organisation (FAO) of the United Nations has set 20 ppb in human foods (FAO, 2004; Fuzhi, 2007). The European Union (EU) has set a maximum value of 4 ppb in adult and 0 ppb in baby foods (FAO, 2004). Although the paddy in the present study was safe according to the FAO standards, the aflatoxin levels were well above the EU standards. The highest average aflatoxin level of 18 ppb was recorded in Lira (north) district while the values from other regions were significantly different within the same level of 9.78 – 12.25 ppb (P = 0.000462). The prolonged heaping of paddy immediately after harvest has been associated with aflatoxin contamination. Candia *et al.* (2010a) reported that 38.6% of the smallholder farmers in the entire study area heaped paddy for at least 3 days before threshing and subsequent drying. Other studies in the same districts have also indicated that about 5.5% of the farmers in the north heap paddy up to 7 days before threshing (Candia *et*.al, 2010b). The long duration of heaping paddy which is a bad post-harvest practice could possibly be one of the reasons why aflatoxin contamination in paddy was high in all the four regions of the country and much higher in Lira district which was 18 ppb (Table 1).

There were variations in aflatoxin contamination among the commonly grown rice varieties (Table 2). Compared to other varieties, *Supa* variety obtained from Lira district seemed to be more susceptible to aflatoxin contamination of 18.25 ppb than other rice varieties. However, it could not be verified since the samples were not subjected to the same conditions from harvesting to storage. The rancidity levels (FFA % Oleic acid) in the samples from Butaleja district (east) and Lira district (north) were higher than similar samples from other regions (Table 1). The samples obtained from Butaleja and Lira districts had stayed in store for two – six months and were *Kaiso* and *Supa* varieties, while those from the other districts were fresh and were *NERICA* 4 mixed with other varieties. The varietal difference as well as storage time could be responsible for differences in FFA. Oleic acid has one double bond which easily breaks down during storage to produce the bad odour. Technically, 0.03%, of oleic acid in the paddy does not render the rice product inedible to humans or livestock. However with the prolonged storage; it may interfere with consumer acceptability particularly with off flavours.

Similar to paddy results, the aflatoxin values in the milled rice were below the maximum recommended value of 20 ppb set by FAO for human and animal feeds. Although the milled rice was safe according to the FAO standards, the aflatoxin levels were still well above the maximum values set by EU for adult and baby foods. It is therefore clear that milled rice from Uganda cannot be exported to European markets. The highest average aflatoxin level of 19.5 ppb was recorded in Lira (north) district while the values from other regions were relatively low but within the same level of 9.6 – 11.0 ppb. The difference was attributed to prolonged heaping period before threshing in Lira. Apparently, the hyphae of the aflatoxin-producing fungus *Aspergillus flavus* penetrate through the rice husks and attack the grain. Indeed, Robinson (1966) observed that *A. Flavus* penetrated an insect integument which is physiologically tougher than rice husk. The highest rancidity levels of 0.06% (FFA % Oleic acid) was recorded in the samples from Nakaseke (central) district and the lowest value (0.01%) was recorded in samples obtained from Hoima (west) district (Table 3). Similar to explanation under paddy, the maximum 0.06% of oleic acid in the milled rice from Nakaseke district does not render the rice product inedible to humans or livestock. However, with the prolonged storage, it may interfere with consumer acceptability particularly with off flavours.

Conclusions

Smallholder farmers in Uganda who use rudimentary practices and technologies for carrying out all the post-harvest operations, supply low quality paddy to rice millers. Consequently, the milled rice from such paddy is of market value. Notwithstanding the low paddy quality, the milling practices and poor milling technologies also have effect on the physical quality of the milled rice. The milled rice in most cases registered a high level of broken grain and exhibited low degree of whiteness which undermines their marketability since most Ugandan consumers regard them as desired quality attributes. High levels of foreign matter especially, stones were detested by the clientele. The high broken, foreign matter and aflatoxin levels in milled rice reduced the competitiveness of Uganda as a country in international rice trade.

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