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Incidence of Aflatoxins, Heavy Metals and Pesticide Residues Contamination in Imported and Locally Grown White Rice in Uganda

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Abstract: ***There is increased global interest in the safety of rice because rice is a staple food for half of the world's population and its safety influences consumers' health. This study aimed at assessing the levels of aflatoxins (B1, B2, G1, and G2), heavy metals (Arsenic, Lead, and Cadmium), and organochlorine pesticide residues (OCPs) in imported and local rice in Uganda so as to compare their incidence and level of contamination. Rice (n = 305 samples) was collected from 4 major rice-producing districts and 4 rice entry points in Uganda from January 2018 to December 2019. Thin-layer chromatography was used to analyze samples for aflatoxins, atomic absorption spectrophotometry for heavy metals, and gas chromatography for organochlorine pesticide residues. The mean total aflatoxin contamination in imported rice (2.14±3.73 µg/kg) was higher than (0.01±0.09µg/kg) reported in local rice; with 14 (11.9%) samples above the Ugandan standard specification of 10 µg/Kg. The mean cadmium and lead levels (0.52±1.15mg/kg and 0.79±1.27mg/kg) exceeded the Ugandan Standard (US 738: 2019) and Codex Standard (CXS 193-1995) specifications of 0.1 mg/kg and 0.2mg/kg, respectively. OCPs including Aldrin, Endosulfan sulphate, 4, 4-DDE detected in imported rice were higher than the maximum residual limit (MRL) of Codex Alimentarius Commission. Heavy metal and OCP contamination of imported rice in Uganda may predispose rice consumers to toxicological risks. Handling and transit conditions for imported rice should be improved to reduce on aflatoxin contamination. Contamination of low land rice with heavy metals can be managed through enforcement of environmental laws that control wetland pollution. Continuous monitoring of heavy metals and OCPs in both local and imported rice is proposed to promote food safety and protect human health.***

Keywords: Aflatoxins, Heavy metals, Pesticide residues, rice, Uganda

1. Introduction

Rice (*Oryza sativa L.*) is a staple food in Uganda with a rising consumption rate of 2.1% per year (Ikuchi et al., 2014). In Uganda, 30% of households consume rice with the average per capita rice consumption being 8.5Kg (FAOSTAT, 2021). There are two main categories of rice grown locally in Uganda; lowland varieties (60%) and upland varieties (40%) (LTS International, 2017). Although there has been an upward trend in rice production in Uganda, the demand for rice still surpasses local production, thereby necessitating rice importation (FAOSTAT, 2021). Rice is susceptible to high concentration of contaminants when compared to other crops grown under similar conditions (Raquel et al., 2016) . Accumulation of contaminants in rice is associated with the plant characteristics, cultivation conditions as well as postharvest practices, which optimize the transfer of such elements into rice (Harine et al., 2021).

Rice (*Oryza sativa L.*) cultivated in flooded irrigation conditions and high moisture levels, is susceptible to mold infection and subsequent aflatoxin contamination (Chauhan, 2017; Marin et al., 2013). Aflatoxins (AFs) are one of the highly toxic secondary metabolites produced by Aspergillus (Asp.) mold species such as *Asp. flavus*, *Asp. parasiticus* and *Asp. Nomius* (Chauhan, 2017). The occurrence of AF (B1, B2, G1 and G2) in rice has been reported in several sub-Saharan and Asian countries in previous studies (Elzupir et al., 2015; P. Kumar et al., 2017; Taghizadeh et al., 2018) . Of the four main types of AFs (B1, B2, G1, and G2), aflatoxin B1 is the most toxic and prevalent in food (Ruyck & Sarah, 2015, Carballo et al., 2019) . There is increased attention globally on the presence of AFs in food because of their carcinogenic, immunosuppressive, and growth retardation effects in humans (Kumar et al., 2017). Exposure to aflatoxins is known to cause more than 80% of hepatocellular carcinoma cases that occur in low-income countries (Yang et al., 2019) .

Due to industrialization and urbanization, toxic elements such as arsenic (As), cadmium (Cd), and lead (Pb), originating mainly from mining, industrial processes, pesticides, chemical fertilizers and atmospheric deposition; have become a major threat to food safety (Jacob et al., 2018; Otitoju et al., 2019; Wu et al., 2018) . As, Cd and Pb pose food safety risks because they rapidly spread out at different levels in the food chain through bioaccumulation (Emumejaye, 2014b) . Of all the rice planted in Uganda, low land varieties take up 60% (Kikuchi et al., 2013; LTS International, 2017) . Heavy metals from mining activities and industries may be taken by runoff to the wetlands (Simon et al., 2016) ; hence, low land rice grown in Uganda is susceptible to heavy metal contamination. Most of the rice imported to Uganda is sourced from Pakistan, India, and Vietnam, which similarly grow rice in paddies prone to heavy metal contamination (Majeed et al., 2013, Satpathy et al., 2014) . Heavy metals are essential to maintain various biochemical and physiological functions in living organisms when in very low concentrations; however, they become highly hazardous when they exceed certain threshold concentrations and may cause acute or chronic poisoning (Jaishankar et al., 2014). Arsenic causes injury to the pancreatic beta cells, apoptosis and may result in insulin-dependent diabetes mellitus (Simon et al., 2016) . Exposure to Cd may cause nephritis, kidney and liver damage, hypertension, anaemia, and osteoporosis (Bosch et al., 2015; Satarug, 2018). Lead can cause kidney disease, bone and stomach pain, nerve damage, spontaneous abortion and anaemia (Obeng-gyasi, 2018).

The rapid increase in population growth and the need to maintain food security especially in developing countries has increased the use of pesticides (Olisah et al., 2020). Farmers use pesticides to prevent crop damage and increase productivity (Reiler et al., 2015). Pesticides are also used on rice postharvest to prolong storage life (Lesa et al., 2017). Organochlorine pesticides are a major group of pesticides used by rice farmers in developing countries due to their cheap cost, broad spectrum of activity, lower persistence and lower toxicity (Khammanee et al., 2020). Improper selection and use of pesticides on food can result in undesirable levels of residues even after processing hence; pesticide residues in rice can constitute an important food safety and health hazard (Sataloff et al., 2017). Pesticides residues can cause short-term negative effects such as headaches and nausea as well as chronic impacts like cancer, endocrine malfunction and disruption of the reproductive system (European Parliament, 2021) .

Several studies have shown that rice is often contaminated with of aflatoxin, heavy metals and organochlorine pesticide residues in different countries (Kim et al., 2016; De Ruyck *et al.,* 2015; Bempah *et al.,* 2016, Yang *et al.,* 2019), nevertheless, information regarding rice contamination in Uganda is lacking. Quality characterisation of rice in relation to consumers and export markets is defined by chemical and microbial attributes such as aflatoxins, heavy metals and pesticide residues (Shabbir et al., 2013). To control contaminants in rice, there is a need to determine if they exist and quantify their levels in a pursuit to ensure safe food supply. Thus, the objective of this study was to determine and compare levels of aflatoxins (B1, B2, G1, and G2), heavy metals (As, Cd, and Pb) and organochlorine pesticide residues in imported and locally grown rice in Uganda.

2. Methodology

2.1 Study area

The study trailed the trade flow routes of imported and locally produced rice on the Ugandan market (figure 1). Imported rice in Uganda comes in through two routes; the eastern and southern route. Imported rice samples were collected from Malaba and Busia for the eastern route while rice from the southern route was collected from Mutukula and Kikagate entry points. Local rice consists of lowland rice varieties that were collected from Butaleja and Hoima and upland rice, which was picked from Gulu and Iganga districts.

2.2 Study design

The study had two factors (imported and locally grown rice); each with two levels (imported-eastern/southern and local-lowland/upland rice).

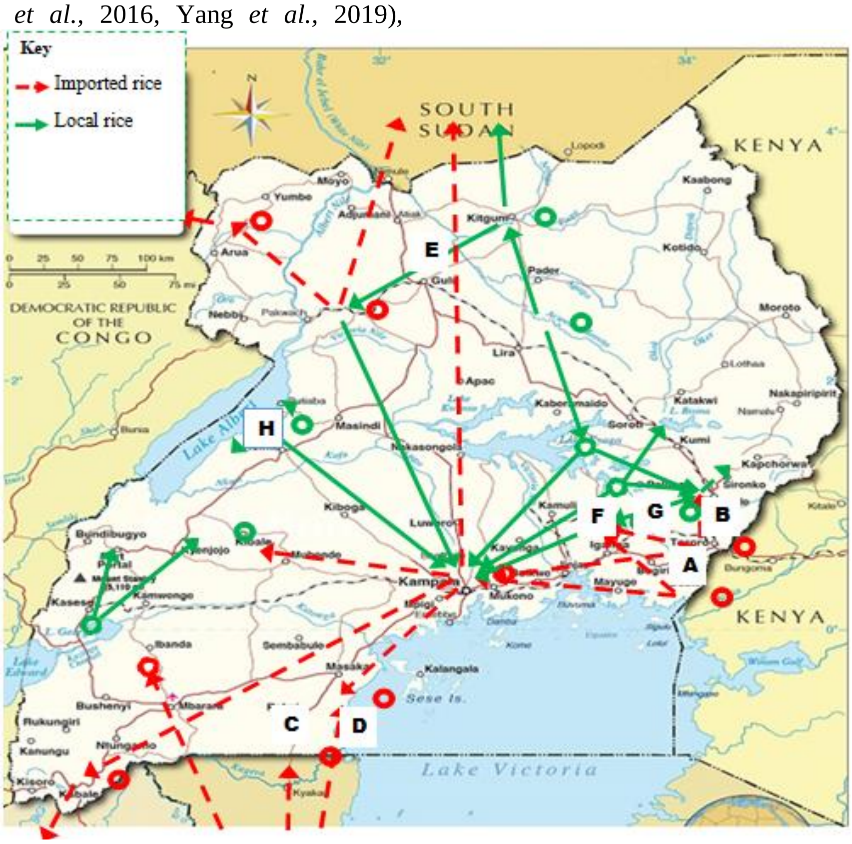

Figure 1: Rice trade flow routes in Uganda (Source: LTS International, 2017)
A: Busia, B: Malaba, C: Mutukula, D: Kikagate, E: Gulu, F: Iganga, G: Butaleja, H: Hoima.

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2.3 Sampling procedure

The cross-sectional study was conducted between January 2018 to December 2019. In this study, purposive sampling was used to select the districts where rice is grown and entry points for imported rice. A multistage sampling technique was employed and the sampling frame was the district, village, and finally a household that grows rice in a given district for local rice. Similarly, a specific entry point for imported rice was selected and samples picked off rice consignments as per the sampling plan. Simple random sampling was used to collect 30 samples from each of the 4 main districts that grow lowland and upland rice (Taherdoost et al., 2016). Lowland rice samples were collected from Butaleja and Hoima while upland rice samples were picked from Gulu and Iganga districts. Imported rice in Uganda comes in through two major routes, the eastern and southern routes. Sample size per given route was determined as stated by Bukhari, (2020). Importedrice samples (n=185) were picked from the four major rice entry points in Uganda including Mutukula (n=123) and Kikagate (n=24) from the southern route, and Malaba (n=24) and Busia (n=14) from the eastern route.

Sampling was done according to the method described in AOAC official method No.977.16 (2005). To obtain a representative portion, 500-1000 g were collected using a sample probe by piercing jute bags diagonally from 3 points. Rice samples were sealed in sterile, waterproof sampling bags and labelled with the appropriate sample numbers. All samples were placed in a cold box with icepacks (¯8ºC) and transported to the laboratories at the Uganda National Bureau of Standards, located in Bweyogerere-Kampala. In the laboratory, the samples were ground using an Eberbach 8017 explosion–proof blender (Haverhill– Massachusetts, USA) to obtain a finer powder. The powdered rice was sieved into particles ≤ 1 mm by passing through sieve No.20. The powdered samples were kept in airtight containers at-20ºC to prevent additional fungal contamination and were processed in 3 days' time.

2.4 Analysis of aflatoxins in rice

Thin-layer chromatography (TLC) was used for the detection of AFs as described in the AOAC official method No.975.36/968.22 (AOAC, 2005) . Aflatoxins B1, B2, G1, and G2 were determined according to the AOAC method 970.44A. Aspectrophotometer (Genesys 10 UV-Vis, Thermo Electron Corp., Madison, Wis., U. S. A.) was calibrated for the correction factor according to method 971.22B, AOAC (2005). Standard stock solutions (10 µg/ml) of each aflatoxin B1 (AFB1), B2 (AFB2), G1 (AFG1) and G2 (AFG2) were prepared according to method 970.44A, (AOAC, 2005)

2.5 Analysis of heavy metals in rice

The analysis of heavy metals was doneusing an Atomic absorption spectrophotometer (Model Varian Spectra AA 250 plus) following the method in AOAC 999.10 (AOAC, 2002)

2.6 Analysis of organochlorine pesticide residues in rice

The extraction procedure for organochlorine pesticide residues was done according to methods described by AOAC International Official Method Vol.90, No.2, (2007), pp.485-520 (AOAC, 2007). Gas chromatographic analysis was done using a Varian CP-3800 gas chromatograph (Varian Associates Inc. USA) equipped with 63Ni electron capture detector. A volume of about 1 µL of the extract was injected and the separation was performed on a fused silica gel capillary column. The carrier and makeup gas was nitrogen at 35°C blown in at a flow rate of 1.0 and 29 ml/min respectively. The injector and detector temperatures were 270°C and 300°C respectively. The column oven temperature was programmed as follows: 80°C for 1 min to 18°C at 25°C/min and up to 300°C at 5°C/min held for 1 min.

2.7 Data Analysis

Statistical analysis was done using the SPSS software (Version 15, SPSS Inc, and Chicago, USA). Results were expressed as mean ± standard error and variations were considered significant when $P < 0.05$. Analysis of differences in means of local and imported rice samples was done using student's t-test at a 5% level of significance.

3. Results and Discussion

3.1 Aflatoxins in imported and local rice in Uganda

The aflatoxin content in imported and locally grown rice in Uganda is shown in Table 1

Table 1: Incidence and level of aflatoxins contaminationof ricein Uganda

Rice Category	Incidence of Aflatoxin contamination n (%)	Samples above 10 (µg/Kg)	Range of TAF (µg/Kg) (se)	Mean TAF (µg/Kg)	Mean AFB1 (µg/Kg)	Mean AFB2 (µg/Kg)	Mean AFG1 (µg/Kg)	Mean AFG2 (µg/Kg)
Total Imported rice (n=185)	117 (63.3)	14 (11.9)	17.34 (0.27)	2.14 ± 0.27^{b}	0.89 ± 0.12^{b}	0.88 ± 0.10^{b}	ND	ND
Eastern Rice (n=38)	29 (76.3)	10 (35.5)	17.34 (0.92)	4.90 ± 0.88^{c}	1.97 ± 0.39^{c}	1.35 ± 0.26^{c}	ND	ND
Southern rice (n=147)	88 (59.7)	4 (4.5)	13.59 (0.22)	1.43 ± 0.22^{b}	0.86 ± 0.10^{b}	0.56 ± 0.10^{b}	ND	ND
Total Local Rice (n=120)	27 (22.5)	1 (3.7)	10.73 (0.09)	0.12 ± 0.09^{a}	0.05 ± 0.03^{a}	0.02 ± 0.01^{a}	ND	ND
Lowland rice (n=60)	11 (18.3)	0 (0.0)	0.232 (0.018)	0.03 ± 0.01^{a}	0.02 ± 0.01^{a}	0.01 ± 0.01^{a}	ND	ND
Upland rice (n=60)	16 (26.7)	1 (6.3)	10.73 (0.18)	0.21 ± 0.18^{a}	0.08 ± 0.05^{a}	0.01 ± 0.01^{a}	ND	ND

1. MRL means maximum residual limit, TAF means total aflatoxins, se means standard error, ND means not detected.
2. Results are means ± standard error. Means in the same column having the same superscripts (a, b, c, d) are not significantly different (p>0.05).
3. Total aflatoxin specification is<10 µg/Kg and AFBI, AFB2, AFG1 and AFG2 is <5 µg/Kg as stated in US 738: 2019

The incidence of aflatoxin contamination was 144 (47.2%) out of the 305 rice samples tested and15 (4.9%) were above the Ugandan Standard specification of 10 µg/Kg. The incidence and mean total aflatoxin concentration were higher in imported rice as compared to local rice (table 1). The mean concentration of AFs detected in rice imported through the eastern route (4.90±0.88µg/Kg) was significantly higher (p>0.05) than that of the southern route (1.43±0.22 µg/Kg). Rice imported through the eastern route from India, Vietnam and Pakistan undergoes repeated handling, poor transportation conditions and a prolonged period of time in transit. These conditions allow rice grains to pick up moisture from the atmosphere and from metabolic water of the respiring grain to levels suitable for growth of storage fungi and subsequent AF production and contamination (Taligoola et al., 2011). Conversely, the incidence of AF contamination in rice imported through the southern route may be attributed to the practice of middlemen consolidating rice from different Tanzanian farms as observed by Nkuba et al., 2016, which increases the risk of AF cross-contamination. In addition, poor handling of rice consignments as traders smuggle rice to Uganda due to the Tanzanian government's rice export ban and high export tariffs could explain AF contamination in rice imported through the southern route. However, local rice is commonly consumed immediately after harvest, which reduces the risk of AF contamination (Taligoola et al., 2010). For locally grown rice, there was a higher incidence of AF contamination in Upland rice (26.7%) than in lowland rice (18.3%). Consequently, there was a significant difference (p<0.05) in the mean TAF levels between upland (0.21±0.18µg/Kg) and lowland rice (0.03±0.01µg/Kg). In a study carried out in six provinces of China, geography contributed to the differences in mean TAF levels as reported by Lai et al., (2015) . Higher aflatoxin contamination was reported in rice from south China, where hot and wet climatic conditions observed favour fungal growth and subsequent aflatoxin contamination in rice. Rice from northeast China, where the climate is hot and wet in summer; but cold and dry in winter reported lower aflatoxin contamination.

AFB1 and AFB2 were similarly detected in all 144 aflatoxin-contaminated rice samples. The levels of AFB1 and AFB2 detected in contaminated rice samples were below the regulatory specification of <5µg/Kg stated in the Ugandan Standard (US 738: 2019). The mean AFB1 level in imported rice was 0.89±0.12µg/Kg, which was significantly (p<0.05) higher than 0.05±0.03µg/Kg reported in local rice. Likewise, higher levels (p<0.05) of AFB2 were reported in imported rice (0.88±0.10µg/Kg) compared to local rice (0.02±0.01µg/Kg). AFG1 and AFG2 were not detected in any rice sample tested. The optimal temperature for AFs production range between 20 to 35 °C (Al-Zoreky & Saleh, 2019). The temperature within the optimal range favors the production of AFB1 and AFB2. In contrast, a low temperature of about 10°C favors the production of AFG1 and AFG2 (Lai et al., 2015) . The findings of this study support the above-mentioned facts. Uganda has a warm tropical climate, with high temperatures ranging from 25-29°C that favors the production of AFB1 and AFB2. Imported rice in Uganda comes from Pakistan, India, and Vietnam, which similarly experience tropical climates. These hot and humid climatic conditions favor the production of AFB1 and AFB2. Further more, given that the growing conditions for both local and imported rice are the same but AF means are significantly different, handling and transit conditions could probably explain the higher values observed in imported rice.

Published data on the levels of AFs in rice on the Ugandan market is limited. The results in this study were similar to total AFs and AFB1 values of 0.052-2.58µg/Kg and 0.014-0.123µg/Kg respectively reported in various rice samples tested in Saudi Arabia (Al-Zoreky & Saleh, 2019). In Pakistan, Majeed et al., (2013) reported higher levels of both total AFs (8.9-12.5 µg/Kg) andAFB1 (4.9-8.8 µg/Kg) in rice when compared to this study. In Scotland, AFB1 levels were ≤10µg/Kg in rice varieties originating from India and Pakistan (Ruadrew et al., 2013)

3.2 Heavy metals in imported and local rice in Uganda

Results in Table 2 show the mean concentration of arsenic, cadmium and lead in imported and local rice in Uganda.

Table 2: Mean heavy metals concentration in imported and local rice in Uganda

Rice category	Incidence of As above MRL n (%)	Mean Arsenic concentration mg/Kg	Incidence of Cd above MRL n (%)	Mean Cadmium Concentration mg/Kg	Incidence of Pb above MRL n (%)	Mean Lead concentration mg/Kg
Imported rice (n = 185)	31 (16.8) ^{b}	0.06±0.003^{a}	38 (20.9) ^{c}	0.52±0.084^{b}	57 (30.8) ^{b}	0.79±0.094^{b}
Eastern route (n =38)	30 (79.0) ^{b}	0.14±0.008^{b}	8 (21.1) ^{b}	0.50±0.174^{b}	9 (23.7) ^{a}	0.68±0.235^{b}
Southern route (n =147)	1 (0.68) ^{a}	0.04±0.001^{a}	30 (20.4) ^{c}	0.52±0.089^{b}	48 (32.7) ^{b}	0.80±0.101^{b}
Local rice (n = 120)	86 (71.7) ^{d}	0.11±0.004^{a}	0 (0.0) ^{a}	0.05±0.002^{a}	11 (9.2) ^{a}	0.11±0.004^{a}
Lowland rice (n = 60)	57 (95.0) ^{c}	0.13±0.003^{b}	0 (0.0) ^{a}	0.07±0.002^{a}	8 (13.3) ^{a}	0.14±0.012^{a}
Upland rice (n =60)	29 (48.3) ^{b}	0.09±0.006^{a}	0 (0.0) ^{a}	0.03±0.002^{a}	3 (5.0) ^{a}	0.09±0.007^{a}

1. Results are means ± standard error. Means in the same column having the same superscripts (a, b, c, d) are not significantly different (p>0.05)
2. Results in bold exceeded the standard specification. As=0.1 mg/Kg (US 738: 2019), Cd=0.1 mg/Kg, (US 738: 2019), Pb=0.2 mg/Kg (CXS 193-1995).

Arsenic concentration in imported and local rice in Uganda

This study showed that the incidence of arsenic contamination above the standard specification of 0.1 mg/Kg (US 738:2019) was 117 out of 305 samples tested (Table 2). Local rice had a higher prevalence 86 (71.7) of arsenic contamination as compared to imported rice 31 (16.8). Results from this study indicate that there was no significant difference ($p>0.05$) between the mean values of As in imported (0.06±0.003mg/Kg) and local rice (0.11±0.004mg/Kg). Concentration of arsenic ranged from 0.04mg/Kg in rice imported via the southern route to 0.14mg/Kg in rice imported via the eastern route. Local rice had a mean arsenic concentration ranging from 0.13±0.003mg/Kg and 0.09±0.006mg/Kg for upland and lowland rice, respectively. The fact that low land rice has a higher arsenic value than upland indicates that Ugandan wetlands have higher levels of arsenic and action should be taken to control contamination as evidently seen in the rice value chain. Rice imported through the eastern route and lowland rice had a mean arsenic concentration above the MRL of 0.1mg/Kg. Arsenic concentration in rice varies according to the soil where the rice was cultivated, water used for farming and the variety of rice (Shraim, 2017; Simon et al., 2016) . The concentration of arsenic observed in this study was similar to the range of 0.09 ± 0.03mg/Kg and 0.060-0.094 mg/Kg reported in several other studies such as China (Kong et al., 2018) and Senegal (Ndong et al., 2018), respectively. Continuous monitoring and screening of rice on the Ugandan market is proposed to control contaminants and promote food safety.

Cadmium concentration in imported and local rice in Uganda

The incidence of cadmium contamination above the 0.1mg/Kg standard specification was 38 (29.9) and 0 (0) for imported and local rice, respectively (Table 2). Cadmium levels in imported rice (0.52±0.084 mg/Kg) were higher ($p<0.05$) than 0.05±0.002 mg/Kg reported in local rice. The mean Cd levels of imported rice exceeded the Ugandan Standard Specification (US 738: 2019) of 0.1 mg/Kg with the average of imported rice (0.52±0.084mg/Kg) being fivefold the specification. The concentration of Cd in imported rice obtained in this study was similar to those reported in Iran (Abtahi et al., 2017) and Pakistan (Shabbir et al., 2013). Tanzanian polished rice showed a higher concentration of Cd that ranged from 1.24 mg/Kg to 17.97 mg/Kg as reported in a study by Fides, (2016). In that study, the high level of Cd in rice was attributed to excessive utilization of livestock manure and mining activities (Fides, 2016). Cadmium concentration in local rice reported in this study compared favorably with the results reported by Payus et al., (2014). According to Payus & Talip, (2014), the rice grain concentrated the highest Cd levels as compared to other parts of the rice plant such as the root, stem and shoot.

Lead concentration in imported and local rice in Uganda

The incidence of Pb contamination above the maximum residual limit was higher in imported 57 (30.8) than local rice 11 (9.2) (table 2). The study similarly reported a higher ($p<0.05$) mean Pb concentration in imported rice compared to local rice. Imported rice had a mean Pb concentration of 0.79±0.094 mg/Kg, which was more than threefold of the CODEX Standard (CXS 193-1995) specification of 0.2 mg/Kg (Codex Alimentarius, 2019). Local rice reported a lower mean Pb ($p<0.05$) concentration of 0.11±0.004mg/Kg compared to imported rice. The level of Pb in agricultural soils in which the rice was grown might have influenced the elevated level of Pb in imported rice as explained by Kumar et al., (2020) . While both values for Pb for local upland and lowland were below the set MRL, the fact that low land rice has a higher Pb value than upland indicates that Ugandan wetlands are beginning to accumulate Pb and action should be taken to control contamination. The results in this study are similar to the range of 0.027-5.07 mg/Kg of Pb in white polished Tanzanian rice reported by Simon et al., (2016). A study on white polished foreign and local rice in Ghana showed a much lower concentration of Pb in the rice samples (Asamoa, 2016). For polished rice, the concentration of Pb in foreign rice ranged from to 0.0007 mg/Kg to 0.0505 mg/Kg with an average of 0.0171 mg/Kg while local rice reported a mean concentration of 0.0308 mg/Kg with a minimum of 0.0027 mg/Kg and a maximum value of 0.1106 mg/Kg. Emumejaye, 2014 established a higher Pb concentration of 17.64 mg/Kg in rice imported from India and consumed in Delta state, Nigeria

3.3 Organochlorine pesticide residues in imported and local rice in Uganda

The results in Table 3 show the mean concentration (mg/Kg) of organochlorine pesticide residues in imported and local rice samples in Uganda.

Table 3: Residual mean organochlorine concentration of imported and local rice in Uganda

Pesticide residue	Maximum Residual limit (mg/Kg)	% below maximum residual limit	% above maximum residual limit	Residual mean imported (mg/Kg)	Residual mean Local (mg/Kg)
Aldrin	0.02	98.38	1.62	0.03± 0.01[a]	0.01± 0.01[a]
Heptarchlor	0.02	99.6	0.32	0.02± 0.01[a]	0.01± 0.01[a]
Heptarchlor epoxide	0.02	99.6	0.32	0.02± 0.01[a]	0.01± 0.01[a]
Endosulfan I	0.20	100	0	0.01± 0.01[a]	0.01± 0.01[a]
Endosulfan II	0.20	100	0	0.02±0.01[a]	0.01± 0.01[a]
Endosulfan sulphate	0.20	100	0	0.03±0.01[b]	ND[a]
4, 4-DDE	0.10	100	0	0.03±0.01[b]	ND[a]
Dieldrin	0.02	100	0	ND	ND
cis-Chlordane	0.02	100	0	ND	ND
trans-Chlordane	0.02	100	0	ND	ND
4, 4-DDT	0.10	100	0	ND	ND
4, 4-DDD	0.10	100	0	ND	ND
Lindane	0.01	100	0	ND	ND
Methoxychlor	0.02	100	0	ND	ND
Endrin	0.05	100	0	ND	ND
Endrin aldehyde	0.05	100	0	ND	ND

1. ND means Not detected.

2. Results are means ± standard deviation. Means in the same row having the same superscripts are not significantly different ($p>0.05$)

Organochlorine pesticide residues detected in both imported and local rice were aldrin, heptarchlor, heptarchlor epoxide, endosulfan I and endosulfan II. The values of the OCPs detected in imported and local rice were similar. Endosulfan sulfate and 4, 4-dichlorodiphenyldichloroethylene (DDE) were detected only in imported rice. The results in this study show that some OCPs are still in use in some countries and their continued application should be of concern to regulatory authorities. The residual mean concentration of Aldrin, Endosulfan sulphate, 4, 4-DDE detected in imported rice were higher than the maximum residual limit (MRL) recommended by the codex commission (Codex Alimentarius, 2019). The MRL is the maximum concentration of a pesticide residue recommended by the Codex Alimentarius Commission to be legally permitted in or on food commodities. Exposure to a particular pesticide residue above the health safety limit is considered unsafe. The residual means of OCPs in imported rice call for continous monitoring of pesticide residues in all imported rice consignments to ensure food safety and to protect human health. Dieldrin, cis-Chlordane, trans-Chlordane, 4, 4-dichlorodiphenyldichloroethane (DDD), 4, 4 –dichlorodiphenyltrichloroethane (DDT), 4, 4-dichlorodiphenyldichloroethane (DDD), Lindane, Methoxychlor, Endrin, Endrin aldehyde were not detected in both imported and local rice. This points to the fact that the use of certain OCPs have been banned in many countries hence the decline in their use. The concentrations of OCPs in rice samples in the present study were comparable to that reported for rice grains from Dehradun, Punjab Province, Pakistan (Mumtaz et al., 2015) and Chenab, Pakistan (Mahmood et al., 2014) *al.*, 2014). Despite being banned several years ago, extensive use of OCPs remains ongoing in some countries because of their versility (Olisah et al., 2020). Inadequate enforcement of policies to check the importation of OCPs, levity in measures to stop their usage and improper pesticide use by food handlers are responsible for pesticides residues detected in food.

4. Conclusion

The higher incidence and mean total aflatoxin concentration in imported rice as compared to local rice call for improvement in the handling and transit conditions of imported rice to minimize contamination. Regular screening of aflatoxin occurrence in both imported and local rice can reduce on the risk of cumulative exposure to consumers. The higher incidence of arsenic contamination in local rice in contrast to imported rice, calls for enforcement of environmental laws to control pollution of wetlands with heavy metal that are transferred to the food value chains. The levels of cadmium and lead in imported rice exceeded the standard specifications hence may predispose the Ugandan consumers to health-related risks. The results in this study show that some OCPs are still in use in some countries and their continued application should be of concern to regulatory authorities. The residual means of OCPs in imported rice call for continuous monitoring of pesticide residues in all imported rice consignments to ascertain the safety of rice and protect human health.

5. Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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