Macrothink Institute™

Journal of Food Industry
ISSN 1948-545X
2022, Vol. 6, No. 1

Food Safety Knowledge, Attitudes and Practices of Food Handlers along the Rice Value Chain of Uganda

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Received: January 2, 2022 Accepted: February 15, 2022 Published: February 18, 2022

doi:10.5296/jfi.v6i1.19431 URL: http://dx.doi.org/10.5296/jfi.v6i1.19431

Abstract

Food handlers play a critical role in controlling food contamination from "farm to fork". Therefore, inadequate knowledge, poor attitudes and improper practices by food handlers pose a serious challenge to food safety. The aim of this study was to assess the knowledge, attitudes, and practices (KAP) of food handlers along the rice value chain of Uganda with the view of understanding factors that influence contamination of rice with aflatoxins, heavy metals and pesticides. A cross-sectional study, using a structured questionnaire through face-to-face interviews with 252 respondents was conducted in Butaleja, Gulu, Hoima, Kampala, Mutukula, Mbale and Mbarara districts. Categorical data was expressed as frequencies and percentages. The unique predictors of the KAP of rice handlers were defined using multivariate linear regression analysis. About 221 (87.7%) food handlers knew about the occurrence and causes of aflatoxins contamination in rice. Changes in colour (81.7%) and a musty smell (82.9%) were perceived to indicate the presence of aflatoxins. The main pre- and post-harvest aflatoxin preventative practices identified were growing resistant rice varieties (82.9%) and proper drying (79.8%). Food handlers were generally not knowledgeable (73.4%) about heavy metal contamination in rice. All food handlers used pesticides; however, 68.3% had never received formal training in pesticide use. Majority (86.1%) of food handlers were aware of the harmful effects of pesticides but on the contrary, this did not significantly change their practices towards safe pesticide use. At multivariate level, education was the unique predictor for aflatoxins and heavy metal contamination. Pesticide contamination was mainly influenced by district of residence. Therefore, appropriate educational programs organized to train food handlers can promote food safety in the rice value chain of Uganda. Interventions by regulatory agencies to strengthen enforcement of laws related to contaminants through regular surveillance at the farm and retail outlets are necessary to ensure compliance by food handlers.

Keywords: *Rice Value Chain, Knowledge, Attitudes, Practices, Food handlers, Uganda*

1. Introduction

Rice is a priority crop in Uganda's National Development Plan III of 2020/21-2024/25 which aims at enhancing food security, household income, and export promotion (NPA, 2019). However, in recent years, there have been public health and food safety concerns related to aflatoxins, heavy metals and pesticide residues in rice (Chaiyarat et al., 2015; Simon et al., 2016; Kong et al., 2018; Korley Kortei et al., 2019). The prevalence of contaminants in rice underscores the importance of intensive monitoring of rice throughout the entire value chain to prevent or/and reduce the risk of contamination.

Aflatoxin contamination is common in developing tropical countries such as Uganda, where temperature and relative humidity create an atmosphere favorable for the proliferation of aflatoxigenic fungi (Omara et al., 2020). Aflatoxin contamination can occur pre-harvest, at harvesting level and post-harvest (Korley Kortei et al., 2019). Pre-harvest contamination occurs when the fungus infects the kernels via airborne conidia or when the kernels are damaged from insect feeding (Kumar et al., 2017). Harvesting rice immediately after irrigation increases the initial pod moisture and stimulates aflatoxin build up in the rice grains (Hodges & Stathers, 2012). At post-harvest, inefficient and slow drying processes, drying on

Journal of Food Industry
ISSN 1948-545X
2022, Vol. 6, No. 1

bare ground, mechanical damage to the grains at the time of threshing and storage of rice in warm and humid rooms enhance aflatoxin contamination (Ray Lantin, 2019). Socio-economic factors including low aflatoxin awareness, food insecurity, informal marketing systems without strong regulations, inadequate transportation modes, unavailability of harvesting tools and lack of knowledge on appropriate pre and postharvest practices are similarly significant contributors to aflatoxin contamination (Ali, 2019; FAO, 2019). When consumed, aflatoxin-contaminated food results in adverse nutrition and health consequences (Benkerroum, 2020). Chronic exposure to aflatoxin leads to liver cancer and has been linked to childhood stunting (Bbosa et al., 2013). Acute exposure leads to aflatoxicosis, haemorrhage, liver damage, oedema, impaired digestion and death (Sarma et al., 2017). Aflatoxin contaminated rice can also adversely affect trade and the export market share (Elzupir et al., 2015; Ali, 2019).

Rice grown in heavy metal polluted soil or irrigated with heavy metal contaminated water accumulates elevated levels of heavy metals (Zulkafflee et al., 2019). Heavy metal contamination in rice can occur at preharvest and post-harvest level (Simon et al., 2016). Heavy metal contamination at preharvest in rice is caused by activities such as mining and the use of metal-based fertilizers, pesticides and herbicides (Li et al., 2014). The variety of rice grown, the region where rice is grown and the irrigation method used similarly contribute to heavy metal contamination at preharvest level (Honma et al., 2016; Marquez et al., 2018; Mwale, 2018; Simon et al., 2016). Post-harvest contamination of rice is determined by the milling technique and cooking process (Mwale, 2018). Contaminated rice can contribute significantly to dietary intake and bio accessibility of heavy metals (Omar et al., 2015). The continuous use of heavy metal contaminated rice endangers human health due to the bioaccumulation of heavy metals in the body (Zulkafflee et al., 2019). Chronic exposure to heavy metals causes cancer, learning disabilities, skin lesions, abdominal pain, diarrhoea, diabetes, hypertension, respiratory disorders and cardiovascular diseases; hence making it a public health concern (Abtahi et al., 2017; Gomah et al., 2019).

In Uganda, rice cultivation remains traditionally based on subsistence production systems destined for mainly family consumption and marketing of the excess (Ntakyo & van den Berg, 2019). However, with the reduction of the arable land, increasing demand of rice and rising pest attacks, the Ugandan rice value chain is increasingly using pesticides to enhance crop yield and shelf life (Barungi & Odokonyero, 2016; Okello et al., 2019). The amount of pesticide residues found in food depends on the kind and dose of pesticide used during spraying, method of spraying employed, spraying period and integrated pest management both at preharvest and post-harvest level (Öztaş et al., 2018; European Parliament, 2021). Human exposure to pesticides occurs primarily through the oral, dermal and inhalation routes (Chen et al., 2020; Evangelou et al., 2016; Khammanee et al., 2020). Acute pesticide exposure results into excessive sweating, skin irritation, fatigue, dizziness, convulsion, coma and death (Chen et al., 2020; Khammanee et al., 2020; Swagata et al., 2021). Chronic exposure to pesticides may lead to cancer and gene mutation (Kim et al., 2016).

Food handlers knowledge of contaminants, attitudes towards, and the practices applied in relation to the knowledge are important determinants for the safety of food (Swagata et al., 2021). The level of knowledge, attitudes and practices (KAP) of food handlers in rice value chain of Uganda was previously unreported. The aim of this study was to assess the knowledge, attitudes and practices (KAP) of food handlers along the rice value chain of Uganda with the view of understanding factors that influence contamination of rice with aflatoxins, heavy metals and pesticides. This information is critical for guiding policy and intervention strategies to control contamination and promote food safety in the rice value chain of Uganda.

2. Methodology

2.1 Study design and Sample size

A cross-sectional study was conducted between February and May 2021. The study was conducted in Butaleja, Gulu and Hoima, Busia, Mbale, Mutukula and Kampala districts in Uganda. Purposive sampling was used to select the main districts that grow or /and trade in rice in Uganda. Multistage sampling was employed to identify the district, village, and finally a household or shop as the sampling frame. The population size in each selected district was identified from rice farmer groups and trader associations. The estimated sample size was obtained using an automated online calculator (Bukhari sample size calculator, 2020) at a predetermined 95% confidence level and 5% margin of error (Bukhari, 2020). A total sample size of 252 constituting of farmers and traders; Butaleja (n=36), Gulu (n=32), Hoima (n=32), Busia (n=36), Mbale (n=36), Mutukula (n=32) and Kampala (n=48) were selected for this study.

2.2 Data Collection

The questionnaire was pretested using 30 rice handlers who were not included in the final survey. Necessary corrections were made to generate the final data collection tool. A total of 14 research assistants and 3 supervisors who had previous survey experience and could speak local languages were trained on the aim, the importance of confidentiality of information, respondent's right and procedures of interview prior to data collection. Data on food safety KAP of rice handlers was collected through face-to face interviews using the pretested structured questionnaire. The interviews were conducted in the local language for each region, English or both as deemed appropriate by the interviewer. Data collected entailed demographic characteristics of the respondents (district of residence, sex, age, marital status, family size, education and occupation) and knowledge, attitudes and practices of food handlers related to 3 common food hazards (aflatoxins, heavy metals and pesticide residues) along the rice value chain.

2.3 Data Analysis

The data were analysed using the SPSS statistical software, version 20 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to summarize data on the demographics of food handlers (district of residence, gender, age, marital status, family size, education and occupation). Categorical data was expressed as frequencies and percentages. Knowledge was investigated through simple-dichotomy statements with one point awarded for each correct response while no point was given for a wrong response (True-=1, False = 0). The attitudes of food handlers were measured using Likert's rating scale statements using the perception indices (1 = strongly disagree, 2 = disagree, 3 = indifferent, 4 = agree and 5 = strongly agree). Practices were examined using frequency-determination statements (never = 0 or ever = 1). Bivariate regression analysis was used to test the existence of association between the KAP of food handlers and demographic characteristics. Selected independent variables with a significant Pearson correlation at 0.05 level (two tail) were further analysed using multivariable linear regression. The implicit model of the multiple regression was stated according to equation

$$Y = f(X_{1,}X_2, X_{3,}X_{4,}X_{5,}X_{6,} + e_i)$$

Where:

Y = Knowledge attitude and practices of rice handlers related to aflatoxin, heavy metal and pesticides contamination

X_1 =District of residence

X_2 =Gender

X_3 =Age

X_4 = Marital status

X_5 = Education

X_6 = Occupation

e_i =Error term

The relationship between the KAP of food handlers and demographic characteristics was explored. Statistical significance level was set at a p-value <0.05. R square, unstandardized β coefficient at 95% confidence interval were used to identify unique predictors of the KAP of food handlers.

2.4 Ethical Statement

Permission to conduct the study was obtained from the local leaders in each district and chairpersons of the farmer groups and trader organisations in a given area. Respondents were selected basing on their interest to participate. The respondents were adults (> 18 years of age) who were primary decision makers in the rice value chain. The study prepared an informed verbal consent that involved purpose of the research, expected duration of the interview, an explanation that the participants could withdraw from the interview at any time. This statement was read out to each participant before conducting the interview and his or her permission to be involved in the study requested. The study proposed a verbal consent overwritten one because the cross-sectional study was designed to collect descriptive data, responses obtained had no personal, social or political consequences and a significant number of respondents in the rice value chain had a low educational status.

3. Results and Discussion

3.1 Socio-Demographic Characteristics of Food Handlers

The socio-demographic characteristics of food handlers involved in this study are presented in Table 1.

Table 1. Socio-demographic characteristics of the food handlers in the rice value chain of Uganda

Variables	Frequency (n)	Proportion (%)
Gender		
Male	157	67.3
Female	95	32.7
Age (years)		
<20	26	10.3
21-30	46	18.2
31-40	101	40.0
41-50	51	20.2
51-60	15	5.9
>60	12	4.8
Marital status		
Single	27	10.7
Married	225	89.3
Family size		
≤3	40	15.8
4-6	103	40.8
7-9	88	34.9
≥9	21	8.3
Education		
None	28	11.1
Primary	111	44.0
Secondary	90	35.7
Tertiary	23	9.1
Occupation		
Full time farmer	70	27.8
Permanent trader	137	54.4
Temporary trader	45	17.8

*N=252 food handlers.

The study interviewed 252 respondents from 7 districts, with more male (67.3%) than female (32.7%) food handlers. Majority of the food handlers were of middle age with an average of 36.6 years and over 89% were married. The respondents' family sizes varied from 1 to 13 people, and the most represented class (40.8%) had 4 to 6 members. About 88% attended school to acquire some education, indicating a measure of literacy. The majority (82.2%) were engaged full time in the rice value chain as full-time farmers or permanent traders, the rest were temporary traders (17.8%) who joined the rice business when rice was in season.

3.2 Knowledge, Attitudes, and Practices of Food Handlers on Aflatoxin Contamination

The knowledge of food handlers and the unique predictors of aflatoxin contamination are presented in Table 2.

Table 2. Knowledge of food handlers in the rice value chain of Uganda and the unique predictors of aflatoxin contamination

Dependent variables	Frequency (percentage) n (%)	Significant independent variables	Unique predictor	R^2	β coefficient	Standard error	95% Confidence interval for β	
							Lower bound	Upper bound
Occurrence of aflatoxins								
Aflatoxins can be present in rice	221 (87.7)	Education Age Family size	Age	0.38	- 0.90	0.21	- 0.132	- 0.048
Aflatoxin contamination occurs at any time of rice growth	208 (82.5)	Education Age	Education	0.58	0.24	0.26	0.187	0.288
Aflatoxin contamination in rice can occur in the field	76 (30.1)	Education Family size	Education	0.42	0.32	0.30	0.272	0.391
Aflatoxin contamination in rice can occur during storage	207 (82.1)	Education Age	Education	0.32	0.23	0.26	0.181	0.284
Aflatoxins in rice can cross to the table after harvest	174 (69.0)	Education	Education	0.24	0.28	0.03	0.221	0.346
Aflatoxins can be transferred into breast milk	77 (30.5)	Education	Education	0.34	0.38	0.03	0.279	0.395
Aflatoxins can be transferred into milk and dairy products	79 (31.3)	Education District	Education	0.46	0.35	0.03	0.299	0.409
Cause of aflatoxin contamination								
Aflatoxins are caused by fungi	215 (85.3)	Education Age	Education	0.31	0.20	0.02	0.156	0.252
High levels of rain during harvest increase aflatoxin levels	203 (80.6)	Education Age	Education	0.29	0.22	0.03	0.168	0.227
Delayed harvesting promotes aflatoxins contamination	186 (73.8)	Education District	District	0.24	0.05	0.01	0.024	0.072

Slow drying processes promote aflatoxins contamination	219 (86.9)	Education Age	Age	0.33	- 0.05	0.02	- 0.085	- 0.024
Insect infestations promote aflatoxins contamination	206 (81.7)	Education Age	Education	0.54	0.23	0.03	0.173	0.280
Broken rice grains increase chances of contamination	204 (80.9)	Education Age	Education	0.30	0.23	0.03	0.174	0.282
Foreign materials promote aflatoxins contamination	209 (82.9)	Education Age	Education	0.30	0.21	0.03	0.160	0.263
Poor storage conditions promote aflatoxin contamination	221 (87.7)	Education Age	Education	0.33	0.20	0.02	0.153	0.241
Biotic factors that cause aflatoxin contamination*								
Microbial infection	189 (75.0)	Education District	District	0.26	0.43	0.12	0.020	0.067
Insect infestation	199 (78.9)	Education District	Education	0.23	0.20	0.29	0.141	0.257
Rodents in storage	195 (77.4)	Education District	District	0.24	0.04	0.01	0.019	0.066
Abiotic factors that cause aflatoxin contamination*								
High humidity	191(75.7)	Education District	District	0.26	0.05	0.01	0.021	0.068
High temperature	83 (32.9)	Education	Education	0.43	0.38	0.03	0.326	0.436
Poor soils	81 (32.1)	Education	Education	0.39	0.36	0.03	0.306	0.418
Drought stress	83 (32.9)	Education	Education	0.43	0.38	0.03	0.326	0.436

* Means more than one answer was reported (not mutually exclusive).
Values in parenthesis ( ) represent percentage.

Of the 252 food handlers interviewed, 221 (87.7%) knew about the possible existence of aflatoxins in rice. Among the 221 food handlers, 208 (82.5%) knew that aflatoxins can be present in rice at any time of growth. Majority of the food handlers (82.1%) stated that aflatoxin contamination occurs mainly at storage but not in the field (30.1%). The respondents were generally knowledgeable about the fact that aflatoxins can be transferred to the table post-harvest (68.7%). Fewer participants knew that aflatoxins could be present in breast milk (30.5%) and dairy products (31.3%). Biotic factors (mico organisms, insects and rodents) were perceived to potentially cause more aflatoxin contamination as compared to abiotic factors (humidity, temperature, drought and poor soils). Insect infestation (78.9%), rodents in storage (77.4%), and microbial infestation (75%) were the commonest causes of aflatoxin contamination identified by the respondents.

In Uganda, aflatoxin contamination has been mainly studied in maize (*Zea mays L*), sorghum (*Sorghum bicolor* L), peanuts (*Arachis hypogaea* L), sunflower (*Helianthus annus*), sesame (*Sesamum indicum* L) and cassava (*Manihot esculenta*) (Echodu et al., 2019; Omara et al., 2020, Byakika et al., 2019, Angubua et al., 2017; Muzoora et al., 2017). However the possible existence of aflatoxin contamination in rice was reported in Saudi Arabia (Al-Zoreky & Saleh, 2019) and Colombia (Martinez-Miranda et al., 2019). Aflatoxin contamination has been similarly reported to occur at any time of rice growth (Elzupir et al., 2017). High relative humidity, water activity, temperature of rice and insect infestation were reported as critical factors that influence aflatoxin contamination at storage (Kumar et al., 2021). Similar studies reported breast milk and dairy products as major pathways for exposure to aflatoxins for young children (Magoha et al., 2016, Ali, 2019). Absence of stringent regulations and wide spread negligence of food handlers to control aflatoxin contamination in food and feed could possibly explain how aflatoxins find their way into breast milk and dairy products (Lukwago et al., 2019). The food handler's correlation between microorganisms and contamination could possibly explain why they felt that biotic factors are more likely to cause contamination as compared to abiotic factors (Negash, 2018).

The main demographic factors that significantly influenced knowledge of food handlers towards aflatoxin contamination were education, age and district where rice handlers lived (table 2). Multivariate linear regression showed that the level of education was the unique predictor that mainly influenced the knowledge of food handlers towards aflatoxin contamination. A similar study in Ethiopia reported the level of Education, formal training, and proper attitude towards food safety as the significant factors that reduce on food contamination (Alemayehu et al., 2021).

The attitude of food handlers and the unique predictors of aflatoxin contamination are presented in Table 3.

Table 3. Attitude of food handlers in the rice value chain of Uganda and the unique predictors of aflatoxin contamination

Dependent variables	Frequency (percentage)	Significant independent variables	Unique predictor	R^2	β coefficient	Standard error	95% Confidence interval for β	
							Lower bound	Upper bound
Rice that is discoloured may contain aflatoxins								
Strongly agree	158 (62.7)	Education Age	Education	0.406	0.610	0.054	0.504	0.716
Agree	56 (22.2)							
No idea	28 (11.1)							
Disagree	10 (3.97)							
Strongly disagree	0 (0)							
Rice that is differs in smell may contain aflatoxins								
Strongly agree	163 (65.0)	Education	Education	0.393	0.594	0.047	0.502	0.686
Agree	51 (20.2)							
No idea	36 (14.3)							
Disagree	2 (0.79)							
Strongly disagree	0 (0)							
Am aware of the harmful effects of aflatoxins on humans								
Strongly agree	164 (65.1)	Education	Education	0.390	0.572	0.045	0.483	0.661
Agree	54 (21.4)							
No idea	61 (24.2)							
Disagree	0 (0)							
Strongly disagree	0 (0)							
Aflatoxins cause cancer in humans								
Strongly agree	194 (76.9)	Education Age	Education	0.324	0.459	0.048	0.364	0.554
Agree	24 (9.52)							
No idea	34 (13.9)							
Disagree	0 (0)							
Strongly disagree	0 (0)							
Aflatoxins delay child growth								
Strongly agree	23 (9.1)	Education	Education	0.256	0.475	0.51	0.374	0.576
Agree	25 (9.92)							
No idea	171 (67.9)							
Disagree	33 (13)							
Strongly disagree	0 (0)							
Aflatoxin contamination can reduce the price of rice								
Strongly agree	197 (78.2)	Education Age	Education	0.310	0.477	0.052	0.374	0.581
Agree	16 (6.34)							
No idea	37 (14.7)							
Disagree	2 (0.80)							
Strongly disagree	0 (0)							
Aflatoxin-contaminated rice cannot be exported to some countries								
Strongly agree	194 (76.9)	Education	Education	0.308	0.517	0.049	0.420	0.613
Agree	21 (8.33)							
No idea	35 (13.9)							
Disagree	2 (0.80)							
Strongly disagree	0 (0)							

Values in parenthesis ( ) represent percentage.

Food handlers perceived changes in colour (81.7%) and a musty smell (82.9%) to indicate the presence of aflatoxins. Interestingly, 86.5 % had sufficient acuity on the harmful effects of aflatoxins in humans including cancer, but 80.9% were not aware of the fact that aflatoxins delay child growth. Among all the respondents, the proportion that thought that contamination could reduce the price of rice and exportation to some countries was 84.5% and 85.3%, respectively

Comparable to this study, changes in colour and discoloration were reported as an indicator of aflatoxin contamination in cassava, maize and rice (Udomkun et al., 2018, Mahato et al., 2019). Dietary aflatoxin exposure has been reported to cause over 85% of the cases of hepatocellular carcinoma in low-income countries (Palliyaguru & Wu, 2013). Aflatoxins cause stunting by inducing intestinal enteropathy, a subclinical condition of the small intestines, characterised by reduced absorptive capacity and increased intestinal permeability (Smith et al., 2012). Aflatoxin contamination was similarly reported to reduce the price of rice due to damage on the grains, rejection of aflatoxin contaminated produced and creation of a quality based non-tax barrier to trade (Kilimo Trust, 2018; Lukwago et al., 2019; Nkuba et al., 2016).

The main demographic factors that significantly influenced attitude of food handlers towards aflatoxin contamination in rice were education and age (Table 3). Multivariate linear regression showed that the level of education was the unique predictor that influenced the attitude of food handlers towards aflatoxin contamination.

The practices of food handlers and the unique predictors of aflatoxin contamination were presented in Table 4.

Journal of Food Industry
ISSN 1948-545X
2022, Vol. 6, No. 1

Table 4. Practices of food handlers in the rice value chain of Uganda and the unique predictors of aflatoxin contamination

Dependent variables	**Frequency (percentage)**	**Significant independent variables**	**Unique predictor**	**R^2**	**β coefficient**	**Standard error**	**95% Confidence interval for β**	
							Lower bound	**Upper bound**
Preharvest control measures for aflatoxins*								
Selection of healthy seeds	45 (17.9)	Education District	Education	0.28	- 0.06	0.01	- 0.077	- 0.036
Seed treatments with chemicals	131 (52.0)	Education Family size	Education	0.12	0.23	0.41	0.153	0.313
Using resistant/specific varieties	209 (82.9)	Education Age	Education	0.31	0.23	0.03	0.181	0.283
Timely application of fertilisers	174 (69.0)	Education	Education	0.16	0.23	0.03	0.163	0.294
Pesticide application	179 (71.0)	Education	Education	0.17	0.23	0.03	0.170	0.298
Postharvest control measures for aflatoxins*								
Timely harvesting	129 (51.2)	Education Family size	Education	0.09	0.20	0.04	0.119	0.281
Cleaning and sorting before storage	197 (78.2)	Education	Education	0.21	0.24	0.03	0.179	0.292
Proper drying	201 (79.8)	Education Age	Education	0.24	0.22	0.03	0.160	0.274
Proper storage	199 (79.0)	Education	Education	0.22	0.24	0.03	0.181	0.292
Using pesticides	141 (56.0)	Education District	District	0.14	0.06	0.02	0.031	0.089

* Means more than one answer was reported (not mutually exclusive).

Values in parenthesis ( ) represent percentage.

More respondents believed that it was possible to manage aflatoxin contamination at post-harvest as compared to preharvest stage in rice (Table 4). Growing specific varieties of rice in a given region was identified as the main preharvest preventative strategy against aflatoxin contamination. Important post-harvest management practices cited were proper drying (82.9%), cleaning crops before storage (78.2%) and proper storage (79%).

Similarly, aflatoxin management in rice was reported to be more effective at post-harvest than preharvest (Jeyaramraja et al., 2018; Mahuku et al., 2019). Using aflatoxin resistant varieties along with recommended farming practices was one of the preventative strategy recommended in a study in India (Kumar et al., 2021). Comparable to this study, rice farmers in Nigeria identified drying (74.44%), cleaning (70.86%), milling (70.00%), packaging (67.50%) and proper storage (62.99%) as key post-harvest management practices that would control aflatoxin contamination (Adeola, 2020).

The main demographic factors that significantly influenced practices of food handlers with regards to aflatoxin contamination were education, age, family size and districts where rice handlers lived (table 4). Multivariate linear regression showed that the level of education was the unique predictor that mainly influenced the practices of food handlers towards aflatoxin contamination.

3.3 Knowledge, attitude and practices of food handlers on heavy metal contamination

Food handlers' knowledge of heavy metal contamination was presented in Table 5

The respondents were generally not conversant with heavy metal contamination in rice (Table 5). Of all respondents, only 26.6% were aware about the presence of heavy metals in rice. Only 8.7% of the food handlers thought that heavy metal contamination of rice could occur in the field. Among these respondents, 13.1% were aware of heavy metal contamination at the milling stage and felt that rice that is cooked and served could be contaminated by heavy metals (12.3%). Several studies have reported the presence of As, Cd and Pb in rice (Simon et al., 2016, Abtahi et al., 2017, Ndong et al., 2018).

According to a case study in the Jin-Qu Basin of China, heavy metal contamination in the field was attributed to rice's efficient assimilation of heavy metals from soils (Guo et al., 2020). Milling equipment and method of milling have been reported to determine the concentration of heavy metals introduced into food (Oniya et al., 2018, Adu et al., 2020). The level of education was the unique predictor that influenced the knowledge of food handlers towards heavy metal contamination. Similarly, the level of education was the unique predictor that influenced the attitudes of food handlers towards heavy metal contamination.

Table 5. Knowledge of food handlers in the rice value chain of Uganda and the unique predictors of heavy metal contamination

Variables	**Frequency (percentage)**	**Significant independent variables**	**Unique predictor**	R^2	**β coefficient**	**Standard error**	**95% Confidence interval for β**	
							Lower bound	**Upper bound**
Occurrence of heavy metals								
Heavy metals can be present in rice	67 (26.6)	Education District Marital status	Education	0.50	0.36	0.03	0.307	0.408
I am aware of heavy metal contamination of rice in the field	22 (8.7)	Education	Education	0.20	0.16	0.02	0.117	0.195
I am aware of heavy metal contamination during milling	33 (13.1)	Education Marital status	Education	0.32	0.24	0.02	0.192	0.278
I am aware of heavy metals in rice cooked and served	31 (12.3)	Education Marital status District	Education	0.32	0.21	0.02	0.163	0.251

Values in parenthesis ( ) represent percentage.

Table 6. Attitude of food handlers in the rice value chain of Uganda and the unique predictor of heavy metal contamination

Variables	**Frequency (percentage)**	**Significant independent variables**	**Unique predictor**	**R^2**	**β coefficient**	**Standard error**	**95% Confidence interval for β**	
							Lower bound	**Upper bound**
Heavy metals are harmful to human health								
Strongly agree	0							
Agree	28 (11.1)							
No idea	123 (48.8)	Education	Education	0.027	0.175	0.067	0.043	0.308
Disagree	65 (25.8)							
Strongly disagree	36 (14.3)							
Heavy metals cause liver damage in humans								
Strongly agree	0							
Agree	17 (6.8)							
No idea	134 (53.2)	Education	Education	0.069	0.287	0.067	0.156	0.418
Disagree	52 (20.6)							
Strongly disagree	49 (19.4)							
Heavy metals cause stunting in children								
Strongly agree	0							
Agree	17 (6.8)							
No idea	142 (56.3)	Education	Education	0.070	0.289	0.069	0.161	0.420
Disagree	53 (21.0)							
Strongly disagree	40 (16.0)							
Heavy metal-contaminated rice cannot be exported to some countries								
Strongly agree	9 (3.6)							
Agree	16 (6.4)							
No idea	138 (54.8)	Education	Education	0.084	0.313	0.065	0.185	0.442
Disagree	64 (25.4)							
Strongly disagree	20 (7.9)							

Values in parenthesis ( ) represent percentage.

Only 11.1% of the respondents believed that heavy metals were harmful to human health. Some few food handlers (6.8%) knew that heavy metals damage the liver and cause stunting in children. Nonetheless, 11.9 % of the food handlers thought that heavy metal-contaminated rice could not be exported to some countries. Decreased neuro development, delayed growth and early life stunting have been correlated with heavy metal consumption (Gleason, 2017, Cusick et al., 2018). Children absorb heavy metals more readily than adults which in turn cause intestinal malfunction and malabsorption of food in the infants body resulting into stunting (Horton et al., 2013). Regulation of heavy metals is done to demonstrate the capability of the exporting countries to offer food safety protection levels equivalent to those achieved in destination markets (Humphrey, 2017). The level of education was the unique predictor that influenced the attitude of food handlers towards heavy metal contamination.

Growing rice in swampy and flooded conditions and application of heavy metal- contaminated fertilizes and agrochemicals were identified as the main causes of heavy metal contamination in rice. Almost all food handlers were acquainted with cooking rice in uncontaminated water to reduce the risk of heavy metal contamination. A study conducted in China explained that washing and cooking of rice in uncontaminated water lowers the toxicological risk by reducing concentrations and bio accessibilities of Cd, As and Pb (Liu et al., 2018).

The significant demographic factors that influenced practices of food handlers towards heavy metal contamination were education, sex, marital status and districts where respondents lived (Table 7). The level of education was the unique predictor that mainly influenced the practices of food handlers towards heavy metal contamination.

Table 7. Practices of food handlers in the rice value chain of Uganda and the unique predictors of heavy metal contamination

Variables	**Frequency (percentage)**	**Significant independent variables**	**Unique predictor**	**R^2**	**β coefficient**	**Standard error**	**95%Confidence interval for β**	
							Lower bound	**Upper bound**
Practices that cause heavy metal contamination								
Mining	34 (13.5)	Education Marital status District	Education	0.35	0.23	0.02	0.188	0.277
Use of heavy metal contaminated fertilizers	66 (26.2)	Education Marital status District	Education	0.49	0.35	0.03	0.303	0.404
Use of heavy metal contaminated agrochemicals	64 (25.4)	Education Marital status District	Education	0.47	0.34	0.03	0.288	0.384
Irrigation with heavy metal contaminated wastewater	39 (15.5)	Education Marital status	Education	0.38	0.27	0.02	0.230	0.319
Growing rice in swampy and flooded conditions	64 (25.4)	Education Marital status District	Education	0.47	0.34	0.03	0.288	0.385
Disposal of heavy metal contaminated waste on land	8 (3.2)	Education District	District	0.06	0.01	0.01	0.002	0.024
Ways of reducing heavy metal contamination*								
Soaking and rinsing of rice before cooking	13 (5.2)	Sex	Sex	0.09	0.14	0.03	0.083	0.191
Using uncontaminated water to cook rice	249 (98.8)	Education	Education	0.04	0.03	0.01	0.010	0.043
Cooking rice with excess water and draining it when rice softens.	8 (3.2)	Sex	Sex	0.05	0.08	0.02	0.040	0.128

Values in parenthesis ( ) represent percentage

3.4 Knowledge, Attitude and Practices of Food Handlers on Pesticide Contamination

Knowledge of pesticide contamination among the food handlers is presented in Table 8.

Table 8. Knowledge of food handlers in the rice value chain of Uganda and the unique predictors of pesticide contamination

Variables	**Frequency (n) Percentage (%)**	**Significant independent variables**	**Unique predictor**	R^2	**β coefficient**	**Standard error**	**95% Confidence interval for β**	
							Lower bound	**Upper bound**
Have you ever been formally trained on pesticide use?								
Yes	80 (31.7)	District Education Occupation Age	District	0.46	-0.10	0.01	-0.123	-0.070
No	172 (68.3)							
What is your source of information on pesticides?								
Pesticide sellers	92 (36.5)	District Age	District	0.40	0.26	0.02	0.217	0.302
Fellow food handlers	46 (18.3)							
TV/Internet/newspapers	114 (45.2)							
Might you know that some pesticides have been banned?								
Yes	141 (55.9)	Education District	District	0.81	0.09	0.01	0.066	0.103
No	111 (44.0)							
Why have some pesticides been banned?								
Stopped production	20 (7.9)	Education District	District	0.56	−0.23	0.02	−0.270	−0.182
Toxicity	76 (30.2)							
Forbidden by nation	37 (14.7)							
No idea	119 (47.2)							
Have you ever heard of pesticide residues?								
Yes	127 (50.4)	Education District	District	0.67	0.05	0.01	0.035	0.071
No	125 (49.6)							

What are the commonest routes of pesticide exposure?								
Inhalation	190 (75.4)							
Ingestion	56 (22.2)	Education	Education	0.36	−0.37	0.03	−0.429	−0.306
Skin	6 (2.4)							
What symptoms might one have due to pesticide exposure*?								
Skin rash and irritation	217 (86.1)	Occupation Age	Age	0.49	0.07	0.01	0.040	0.090
Headache and dizziness	148 (58.7)	Occupation	Occupation	0.29	−0.40	0.04	−0.047	−0.316
Nausea and vomiting	106 (42.1)	Occupation District	Occupation	0.11	−0.31	0.05	−0.418	−0.200
Excessive sweating	100 (39.7)	Occupation	Occupation	0.06	−0.18	0.05	−0.267	−0.090
Coughing	159 (63.1)	Occupation District	Occupation	0.27	−0.38	0.04	−0.452	−0.298
Eye irritation and redness/blurred vision	144(57.1)	Occupation Family size	Occupation	0.19	−0.28	0.05	−0.380	−0.170
Respiratory distress	98(38.9)	Occupation	Occupation	0.05	−0.16	0.05	−0.251	−0.074
Fatigue	166(66.9)	0ccupation	Occupation	0.25	−0.35	0.04	−0.428	−0.275

* Denotes more than one answer was reported (not mutually exclusive)

Values in parenthesis ( ) represent percentage

Most (68.3%) of the food handlers in this study had never received formal training in pesticide use and safety (table 8). The remaining 31.7% of the food handlers had received some knowledge on pesticide use from television and newspaper articles (45.2%), and pesticide sellers (36.5%). Some of the respondents (30.2%) knew that some pesticides had been banned due to their toxicity. A fair number of respondents (50.4%) had heard of pesticide residues. Inhalation (75.4%) and ingestion (22.2%) were the major reported routes of pesticide exposure. The majority (86.1%) of food handlers in this study were well aware of the harmful effects of pesticides on human health, but on the contrary, this did not significantly change their practices or attitudes towards safe pesticide use.

A similar study on the knowledge and perception of farmers regarding pesticide usage in India stated that 90% of the farmers had not received any training on pesticide use, hence the limited knowledge they had (Sai et al., 2019). Pesticide vendors can be utilized as a source of sufficient and trustworthy information that can lead to a better understanding of pesticide risks and use of preventative measures, even for food handlers that are not highly educated (Sharafi et al., 2018). On the other hand,educated food handlers can read publications and access information through the internet, thus increasing their knowledge (Öztaş et al., 2018). Given that only 30.2 % of the respondents knew about banned pesticides, food handlers should be informed about the names and reason for banning certain pesticides, and the effects they may induce on human health and the environment (Sharafi et al., 2018). A similar study by Gesesew et al. (2016) reported ingestion (88.9%) and inhalation (90.4%) as possible mechanisms of pesticide exposure. Unsafe practices and attitudes towards pesticide use were similarly reported about the rice value chain in Madagascar (Bockel et al., 2016) and Turkey (Öztaş et al., 2018).

Journal of Food Industry
ISSN 1948-545X
2022, Vol. 6, No. 1

Table 9. Attitude of food handlers in the rice value chain of Uganda and the unique predictors of pesticide contamination

Variables	Frequency (n) Percentage (%)	Significant independent variables	Unique predictor	R^2	β coefficient	Standard error	95% Confidence interval for β Lower bound	Upper bound
Pesticides are harmful for human health								
Strongly agree	31 (12.3)	Education District	District	0.683	0.064	0.017	0.032	0.097
Agree	96 (38.1)							
No idea	84 (33.3)							
Disagree	39 (15.5)							
Strongly disagree	2 (0.8)							
Illness is related with pesticide application								
Strongly agree	59 (23.4)	Education District Family size	Education	0.574	0.985	0.071	0.845	1.125
Agree	67 (26.6)							
No idea	69 (27.4)							
Disagree	36 (14.3)							
Strongly disagree	21 (8.3)							
Pesticides can be transferred through rice to humans								
Strongly agree	25 (4.4)	Education District	Education	0.179	0.668	0.096	0.478	0.858
Agree	41 (9.9)							
No idea	69 (27.4)							
Disagree	49 (31.3)							
Strongly disagree	68 (27.0)							
Pesticides are indispensable for high crop yield								
Strongly agree	62 (24.6)	Education District Age	District	0.162	0.207	0.038	0.131	0.282
Agree	84 (33.3)							
No idea	30 (11.9)							
Disagree	57 (22.6)							
Strongly agree	19 (7.5)							

Values in parenthesis ( ) represent percentage.

While 41.6% of the respondents in this study agreed that pesticides are harmful to human beings, 48.4% had experienced medical problems after pesticide application (table 9). However, majority (58.3%) felt that the exposure was higher in the field than through the consumption of rice (14.3%). Majority of the respondents (57.9%) agreed that pesticides are indispensable for high crop yield while 21.8% felt that rice would still perform well with minimal pesticide application. To reduce the risk associated with pesticides,it is also important to educate farmers about alternative cropping systems that are less dependent on pesticides, integrated pest management practices and organic methods of pest control (Öztaş et al., 2018).

Table 10. Practices of food handlers in the rice value chain of Uganda and the unique predictors of pesticide contamination

Variables	**Frequency (n) Percentage (%)**	**Significant independent variables**	**Unique predictor**	**R^2**	**β coefficient**	**Standard error**	**95% Confidence interval for β**	
							Lower bound	**Lower bound**
Where do you keep your pesticides?								
A special pesticide storehouse	229 (8.7)	District						
In the living house	101 (40.1)	Age	District	0.36	0.16	0.02	0.122	0.189
Purchase enough for use	129 (51.2)	Education						
How do you use pesticides?								
According to instruction on the bottle	21 (8.3)	District						
Experience	105 (41.6)	Age						
		Education	District	0.36	0.18	0.02	0.138	0.217
By an expert advice	126 (50.0)	Occupation						
Which type of protection do you use when applying pesticides?								
Face protection	33 (13.0)	Occupation						
Nose protection	127 (50.4)	Education						
Hand protection	59 (23.4)	District	Education	0.61	0.54	0.05	0.445	0.625
Full cloth protection	33 (13.0)	Marital status						

What do you do after applying pesticides?								
Washing hands and face	115 (45.6)							
Showering	37 (14.7)	Age education	Age	0.16	0.32	0.05	0.224	0.408
Nothing	100 (39.7)							
Where do you dispose your leftover pesticide solutions?								
Re-applying on the rice until it is empty	173 (68.7)							
Storing for another application	34 (13.5)	Occupation						
Applying on other crops in the nearby garden	39 (15.5)	Age district	District	0.59	−0.10	0.02	−0.145	0.063
Releasing in water streams	6 (2.4)							
How do you dispose off empty containers?								
Throwing away in the land/water streams	27 (10.7)							
Disposing with regular wastes	116 (46.0)	District						
Keeping for reuse for other purposes	53 (21.0)	Age	District	0.19	−0.18	0.04	−0.253	−0.113
Burying them	8 (3.2)							
Collecting and selling them	49 (19.4)							
What is the most effective way for reducing the risk of pesticides exposure?								
Dose reduction	31 (12.3)	District						
Low-risk products	158 (62.7)	Education	Education	0.38	0.33	0.04	0.249	0.404
Personal protection	63 (25.0)	Occupation						

Values in parenthesis ( ) represent percentage.

The study showed that 40.1% of the food handlers stored their pesticides in the living houses (table 10). Only 8.7% of the respondents' locked pesticides in a chemical store while 51.2% bought only what they would use to spray in a given time. Half of the respondents depended on expert pesticide sellers to fumigate their rice stores, 8.3% read, understood and followed instructions on the pesticide bottles while 41.6% relied on their life experience to mix pesticides. About 50% of the food handlers covered their nose with a handkerchief/piece of cloth while 25% used gloves as they sprayed pesticides. Findings in this study showed low use (13%) of full personal protective equipment (PPE) to reduce occupational exposure to pesticides. Of all the respondents, 45.6 % washed their hands and face after spraying while 39.7% did not. Most respondents were not concerned about over-dosing; 68.7% of them responded that they apply the leftover solution to crops repeatedly while 15.5% applied the leftover pesticides to crops in nearby gardens, which aggregately means unnecessary use of pesticides. Some (2.4%) respondents disposed of the excess pesticide solution into water streams. Empty pesticide containers were thrown on the land (10.7%) or disposed away with regular waste (46%). A few pesticide containers were collected and sold (19.4%) or reused as containers at home for other purposes (21%). Only 3.2% of the respondents buried the empty containers on the farms. Low-risk products (62.7%), personal protection (25.0%) and dose reduction (12.2%) were perceived as the best practices in reducing the risk of exposure. The most common health complaints were skin irritation, fatigue, eye irritation and headache.

Storing pesticides in living areas can increase the potential for pesticide exposure especially for vulnerable groups such as children and pregnant mothers (Gesesew et al., 2016). storage of pesticides in special chemical stores or procuring what one can use at a given time reduces the risk of pesticide exposure. The label on the pesticide plays an important role in the correct use of the pesticide (Öztaş et al., 2018). The fact that 41.6% of the food handlers used pesticides based on experience indicates a general ignorance of the importance of pesticide labels in reducing exposure risk. The main reason mentioned by most food handlers who were not using full PPE was the discomfort under hot and humid conditions, as the environment in Uganda is characterized by high ambient temperatures sometimes exceeding 37 °C. This indicates that food handlers were negligent to pesticide exposure much as they were aware of the risks associated with pesticides. Training on the use of full personal protective equipment and good personal hygiene after using pesticides can reduce occupational exposure (Lekei et al., 2014). Poor pesticide-handling and disposal practices were observed in this study. These can lead to pesticide residues in harvested rice posing a threat to human health. Implementation of a waste management system for safe disposal of pesticide wastes can be very effective especially during agricultural spraying seasons (Gesesew et al., 2016).

The significant demographic factors that influenced practices of food handlers towards pesticide contamination were education, age, occupation, marital status and districts where respondents lived (table 10). The district where respondents lived was the unique predictor that influenced the practices of food handlers towards pesticides.

3.5 Limitations to the Study

The interpretation of results from this study may be limited by the fact that a cross-sectional design was used. Such studies do not allow causal relationships to be established. Furthermore, this study was based mainly on self-reported data, relying on the honesty of respondents, which is subject to bias from recall and social desirability.

4. Conclusion

Understanding food handler's level of KAP regarding contaminants and the unique predictors of their KAP is important for designing sound educational and policy strategies that can control contamination in the food value chain. In this study, rice producers and handlers were generally knowledgeable about aflatoxin and pesticide contamination but not heavy metals. Given that level of education was the unique predictor of food handlers' knowledge, it is important to develop and implement educational programs, which target areas where food handlers' knowledge is weak. Although processors had good attitudes with regards to contaminants, these did not sufficiently translate into good practices. Educational programs, which improve practices of the food handlers using measures that are simple and affordable, can promote food safety. Intervention strategies by regulatory agencies to strengthen enforcement of laws related to contaminants through regular surveillance at the farm and retail outlets are necessary for ensuring compliance to good agricultural, hygiene and manufacturing practices by food handlers that will reduce on contamination.

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.

Acknowledgments

The Islamic Development Bank [Ref ID 600045782:2021-2022] supported this work. Special thanks to the food handlers who were involved in this study.

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