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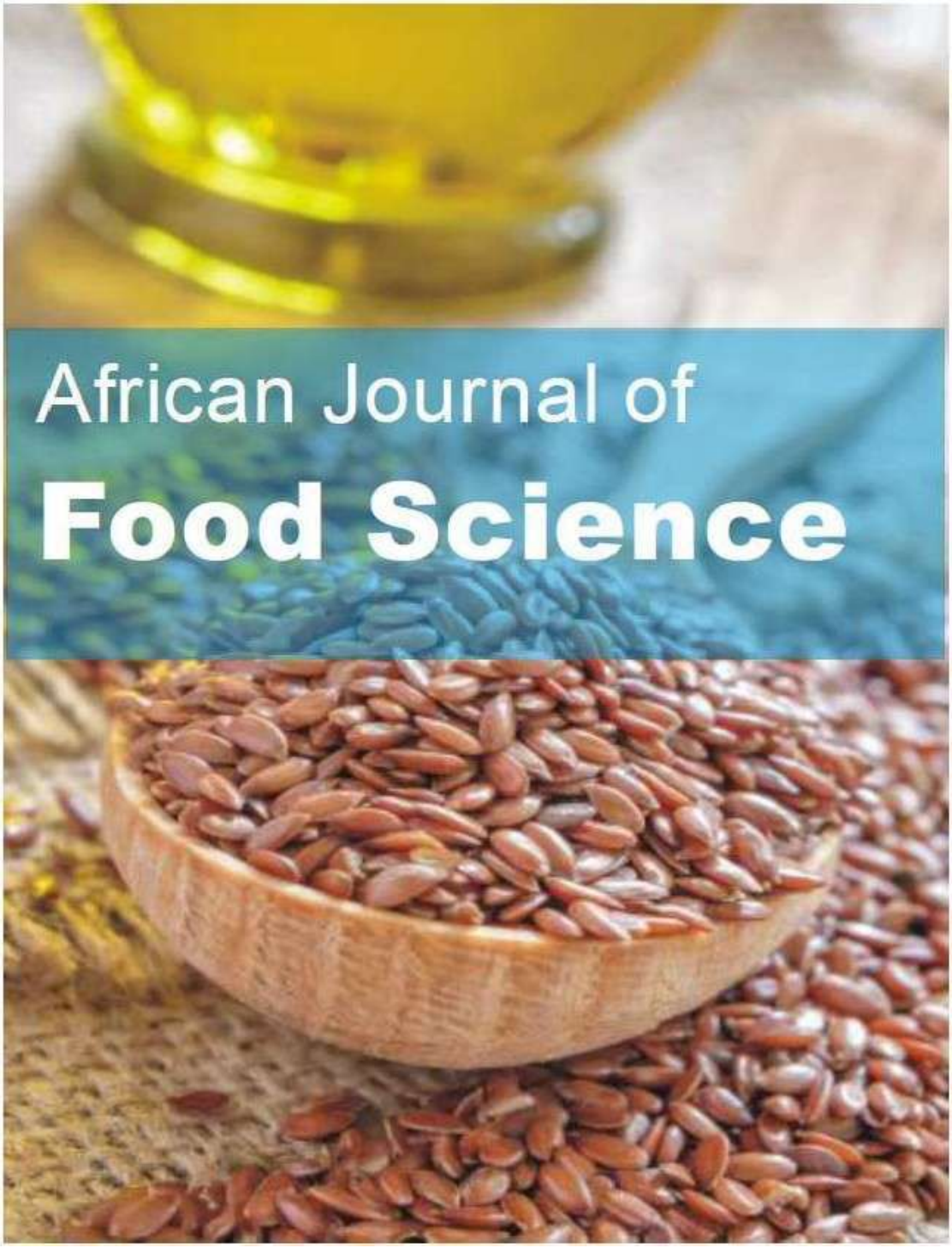

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African Journal of Food Science

Full Length Research Paper

Detection of genetically modified organisms in food products commercialized in Mozambique

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The increasing presence of food and feed products derived from genetically modified organisms (GMO) has led to the development of detection methods that distinguish between foods derived from biotechnology and conventional foods. Many countries have implemented the Regulations for GM products labelling, therefore the need of establish reliable and accurate detection methods for GMO in raw materials and food products. The aim of the present study was to screen foods sold in the selected Mozambican markets for the presence of GMOs. Out of 47 samples analysed, 22 (46%) were positive either for 35S promoter or t-NOS terminator. Results of the event-specific analysis indicated the presence of RRS, Mon863 and TC1507 in 8, 6 and 1 sample respectively. None of the positive samples had a GM label. This study demonstrates for the first time, as far as we know, the presence of GM food products circulating in Mozambican markets, therefore strengthening the need for establish of labelling system and quantitative methods in routine analyses, to ensure compliance with existing regulations.

Key words: Genetically modified organisms, roundup ready soybean, P35S, food.

INTRODUCTION

Maize, soy cotton and canola are the most cultivated genetically modified organisms (GMOs) and they constitute the essential ingredient of many foods (Datukishvili et al., 2015; Turkec et al., 2015; Erkan and Dastan, 2017; Soylu et al., 2020; Ashrafi-Dehkordi et al., 2021). In the mid 90's, GMOs foods, mainly derived from varieties of Roundup herbicide tolerant soybeans (Roundup Ready) and maize (Bt 176) began to be marketed and many more others are in the process of being approved for commercialization (Zhang et al., 2016; Giraldo et al., 2019; Yu, 2021). The resistance of many consumers to these foods which leads to restrictions on consumption and introduction of barriers for commercialization of products derived from GMOs (Smyth, 2017). With the establishment of specific legislation, which may vary by countries or group of

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countries, it was imposed labelling of products that may contain or are produced from GMOs, assess the possible impact on public and environmental health and to give consumers the opportunity of choice (Fraiture et al., 2015; Safaei et al., 2019).

Few African countries have released transgenic crops for farmers use and have access to the genetic modification technology. This scenario is due to the absence or inefficiency of the biosafety legislation and political will. African countries such as South Africa, Zimbabwe, Egypt, Kenya, Tunisia, Algeria, Burkina Faso, Mali, Togo, Ghana Uganda, Sudan and Mauritius has so far implemented this technology and have functional National Biosafety Framework (Gbashi et al., 2021). However, only South Africa, Egypt and Burkina Faso have already advanced to the commercial release crops (Akinbo et al., 2021). While in the European Union, Korea, Japan and Australia the labelling of food and derived products is compulsory (Aburumman et al., 2020; Li et al., 2020; Ashrafi-Dehkordi et al., 2021), most African countries still lack such regulations (Gbashi et al., 2021).

In Mozambique, through Decree no.6/2007, the Council of Ministers approved the Biosafety Regulation on GMOs. The approved document outlines the rules for all activities with GMOs and their products (Boletim da República, 2014). Despite the existence of this legal instrument, little is known about the situation of GMOs in Mozambique, including production, transformation or even trade or use by the public.

The detection of genetically modified (GM) components in compound samples is a challenging task (Turkec et al., 2015). Analytical methods are necessary for detection of GMOs in raw materials, as well as processed products. One of the most commonly applied methods for detection of GMOs is the polymerase chain reaction (PCR) due to its high sensitivity and specificity for DNA detection (Fraiture et al., 2015; Bak and Emerson, 2019; Giraldo et al., 2019; Leão-Buchir et al., 2018; Safaei et al., 2019; Aburumman et al., 2020; Li et al., 2020; Ashrafi-Dehkordi et al., 2021; Park et al., 2021). However quick tests have been also adopted for GMO testing depending on their accuracy, speed and quality. Lateral flow strips, also known as immunochromatographic assays, are the simplest mechanism used to identify the protein expressed by a GMO. They use antibodies to specifically bind and therefore detect the genetically expressed protein by a GM crop (Akiyama et al., 2006; Malik et al., 2018). On the other hand, another type of GMO testing based on protein is the Enzyme-Linked Immunosorbent Assay (ELISA) used to detect the protein expressed by a GM culture (Malik et al., 2018). To date, there are no studies carried out in Mozambique for the detection of GMOs using the PCR method. Therefore, this is the first study that aims to detect the presence of GMOs in food products commercialized in Mozambican markets.

MATERIALS AND METHODS

Samples

This study was carried out in Maputo, Sofala and Nampula, three different sampling areas located in the South, Center and North of Mozambique, respectively. A total number of 47 processed food samples were purchased randomly from different markets and included 6 maize flour, 17 baby food, 5 biscuits, 5 chips, 5 breakfast cereal, 6 sweet corn, 2 soy milk and 1 popcorn (Table 1). Samples were collected in 2009 and 2011. The Certified Reference Materials included 1% RRS, 0 and 10% MON863, 0% and 1% TC1507, and were used in this study for quality controls.

DNA extraction and quality analysis

Genomic DNA was isolated from samples in duplicate using the cetyltrimethylammonium bromide (CTAB) method described by Van den Eede et al. (2000) with some modifications. 1000 µl of pre-heated (65°C) extraction buffer and 10 µl of RNAse (10 mg/ml) were added to 200 mg of each sample and mixed properly. After homogenization, the mixture was incubated at 65°C for 30 min. 10 µl of Proteinase K (20 mg/ml) was added, mixed, and incubated at 65°C for 30 min and centrifuged at 12000 × g for 10 min). The supernatant was transferred to a new 1.5 ml tube containing 500 µl of chloroform and mixed. The material was centrifuged (12000×g, 15 min) and the upper phase was transferred into a fresh 1,5 ml tube containing 500 µl of chloroform and mixed. The material was centrifuged (12000 × *g*, 5 min) and the upper phase transferred to a new 2 ml tube. To the upper phase (aqueous) were added 2 volumes of CTAB, mixed and then incubated for 1 hour at room temperature and the supernatant was carefully discarded after centrifugation at 13 000 x rpm for 5 min. 350 µl of NaCl (1.2 M) and equal volume of chloroform were added to the pellet, mixed carefully and centrifuged at 10 000 × g for 10 min. The upper aqueous phase was transferred into a new tube and 0.6 volumes of isopropanol were added, mixed and incubated at room temperature. The samples was concentrated by centrifugation at 12 000 × g for 10 min before discard the supernatant. Afterwards, the pellet was washed with 70% ethanol and centrifuged at 12 000× g for 10 min, then the pellet air dried at 37°C for 10 min. The pellet was therefore dissolved in 150 µl of TE buffer (pH 7.5) stored at -20°C. To ensure the quality control and reduce false positive or false negative due to the contamination, an environmental control was included on each lote during DNA extraction procedure. Isolated DNA concentration was determined by UV-spectroscopy (Nanodrop 1000, Thermo Scientific) and the absorbance was measured by the ratio of 260 and 280 nm. The DNA quality was assessed on an agarose gel. To ensure that there is no contamination during DNA extraction process, an environmental control (tube with no sample) was included and processed in parallel with the samples.

PCR amplification

All PCR reactions were performed using a thermocycler (Eppendorf Mastercycler Gradient). For quality control of the extracted DNA, primer sets Agh-F3/R4 and QPCR-LecF/GM1R were used for maize and soy endogenous genes. To screen for GM soy and maize products P35SF/R and t-NOS F/R primer sets were used. For the identification of the event-specific Mon 883, TC1507 and RRS, primers Mon863-F/R, MaiY- F1/R3 and RRS were used. The PCR reactions mix contained 1 × PCR buffer, 3 mM $MgCl_2$, 0.2 mM

Table 1. Maize and soy products, description and composition.

Product (Quantity)	Description	Composition
Maize flour TP (2)	Maize meal	Maize
Maize flour FC (2)	Maize meal	Maize
Maize flour SA (2)	Maize meal	Maize
Corn flakes K (2)	Breakfast cereal	Maize
Corn flakes N (1)	Breakfast cereal	Maize
Breakfast cereal (1)	Breakfast cereal	Maize
Corn flakes P (1)	Breakfast cereal	Maize
Crackerbread (1)	Biscuit	Maize
Crackers (1)	Biscuit	Maize, Soy
Chocolate wafers (1)	Biscuit	Soy
Creamy biscuits (1)	Biscuit	Soy
Biscuit M (1)	Biscuit	Maize, Soy
Chips SB (1)	Chips	Maize, Soy
Chips SD (1)	Chips	Maize, Soy
Chips SC (1)	Chips	Maize, Soy
Chips NN (1)	Chips	Maize, Soy
Chips W (1)	Chips	Maize, Soy
Sweet corns R (1)	Sweet corn	Maize
Sweet corns RB (1)	Sweet corn	Maize
Sweet corns J (1)	Sweet corn	Maize
Sweet corns Kw (1)	Sweet corn	Maize
Sweet corns RU (1)	Sweet corn	Maize
Sweet corns T (1)	Sweet corn	Maize
Baby food meal P (4)	Baby food	Maize
Baby food meal PMB (1)	Baby food	Maize, Soy
Baby food meal PC (1)	Baby food	Maize
Baby food meal PN (1)	Baby food	Maize, Soy
Baby food meal PBC (1)	Baby food	Maize, Soy
Baby food (Instant Cereals) (1)	Baby food	Maize, Soy
Baby food (Mixed cereal) (2)	Baby food	Maize
Baby food (Cereals with Honey) (1)	Baby food	Maize
Baby food BPO (cereals) (1)	Baby food	Maize
Baby food (Maize cereals) (1)	Baby food	Maize
Baby food CN (cereals) (1)	Baby food	Maize
Baby food (cereals Maize and rice) (1)	Baby food	Maize
Baby food CN (1)	Baby food	Maize
Baby milk S (1)	Soy milk	Soy
Baby milk N (1)	Soy milk	Soy
Pop corn (1)	Pop corn	Maize

dNTP, 0.4 µM of each primer, 1U of Taq and 5 µl of genomic DNA in a total reaction volume of 50 µl. Primer sets used are listed on Table 2. In order to validate the results, positive and nnegative control (certified reference materials), environmental control and control of the mix (MQ water) were included for each PCR reaction. The PCR cycling condition consists of initial denaturation at 95°C for 10 min, followed by 50 cycles of denaturation at 95°C for 30 s, annealing at 60°C for 30 s and extension at 72°C for 30 s, and a

Table 2. Primers used in PCR reaction.

Target gene	Primer	Sequence (5'-3')	Product size (bp)
Lectin	QPCR-Lec-F	CCA GCT TCG CCG CTT	74
	GM1-R	GAA GGC AAG CCC ATC	
RRS	RRS3J-For	TAG CAT CTA CAT ATA	85
	RRS3J-Rev	GAC CAG GCC ATT CGC	
Adh	Adh-F3	CGT CGT TTC CCA TCT	136
	Adh-R4	CCA CTC CGA GAC CCT	
Mon 863	Mon863-F	GTA GGA TCG GAA AGC	84
	Mon863-R	TGT TAC GGC CTA AAT	
TC 1507	MaiY-F1	TAG TCT TCG GCC AGA	58
	MaiY-R3	CTT TGC CAA GAT CAA	
P35S	35S-F	GCC TCT GCC GAC AGT	80
	35S-R	AAG ACG TGG TTG GAA	
NOS	HA-*nos*-118-F	GCA TGA CGT TAT TTA TGA GAT GGG	118
	HA-*nos*-118-R	GAC ACC GAG CGC GAT AAT TTA TCC	

final extension at 72°C for 8 min.

Agarose gel electrophoresis

The PCR products were analysed on 1.5% agarose gel with DNA safe view stain and visualized by a UV light.

RESULTS AND DISCUSSION

DNA extraction and amplification

The extraction of high-quality DNA is very important for any molecular analysis (Turkec et al., 2015; Soylu et al., 2020; Ashrafi-Dehkordi et al., 2021). The CTAB method for extracting DNA from food products and reference materials yielded DNA of good quality for further analysis however in low quantity. Our results are in line with studies conducted by Pinto et al. (2011), Turkec et al. (2015) and Ashrafi-Dehkordi et al. (2021). The physical grinding process to which the samples were subjected before DNA extraction together with the high level of food processing might be related to the low amount of DNA obtained (Turkec et al., 2015; Coello et al., 2017; Soylu et al., 2020). Arun et al. (2013) and Li et al. (2020) also showed that food processing methods such as heat, may affect the integrity of the nucleic acid. According to Xiang et al. (2015), the methods used to process food, involving physical treatments, chemical changes and biological reactions affect in different ways the integrity of endogenous and exogenous genes. Zhang et al. (2014) evaluated the effects of food processing methods on the degradation of endogenous and exogenous genes on GM rice, where frying was the toughest process for rice crackers while fermentation impacted more on degradation for sweet rice wine. According to Al-Salameen et al. (2012), DNA extracted from processed food is often of low quality, may be absent, present in very low concentrations or even severely damaged, making it not adequate for detection and quantification with molecular analysis. This statement corroborates the finding in the present study.

Screening and event specific detection

DNA extracted from all samples was subjected to soybean and maize-specific PCR to determine if the DNA is amplifiable to prevent false negatives due to non-amplifiable DNA (Alasaad et al., 2016). According to Aburumman et al. (2020), house-keeping genes provides internal control to optimize DNA quantity for PCR reaction with good amplification. The specific primers set targeting Adh and Lectin genes for maize and soybean respectively (Table 2) were used. Expected amplified fragments of 136 bp for Adh (Figure 1) and 74 bp for Lectin genes were detected confirming that tested samples contain either maize or soybean as shown in Table 3. Similar

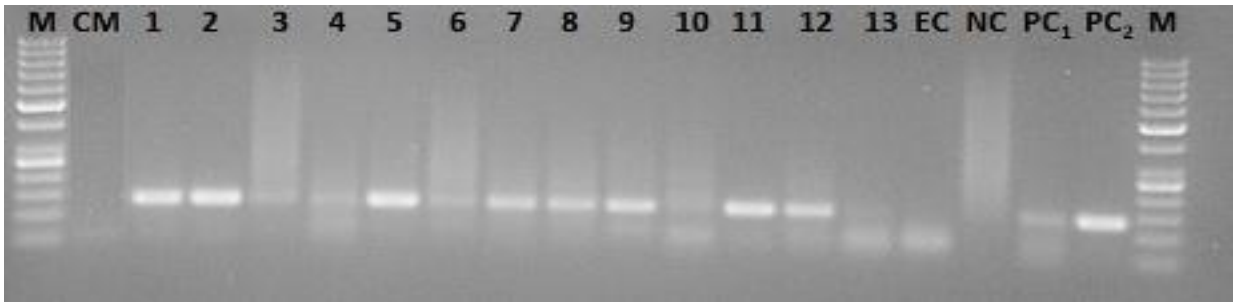

Figure 1. 1.5% Agarose gel electrophoresis of Adh PCR products (136 pb) amplified from genomic DNA. Molecular DNA marker (M); Control of the mix- MQ water (CM); Lines 1,2 maize flour; Lines 3-6 baby food; lanes 7-9 sweet corn; Line 10 Baby milk; Lines 11-13 biscuit; Environmental control (Ec); Negative control - rice (NC); non GM Maize (PC1); Mon 863 10% (PC2).

Table 3. Detection of endogenous genes, specific genes and screening of genetically modified organisms in products contain maize and soy in their composition.

Products	N° samples	(+) endogenous gene		(+) screening		(+) gene specific		
		Lectin	Adh	P35S	NOS	RRS	Mon 863	TC 1507
Maize flour	6	0	6	2	2	0	0	0
Baby food	17	5	7	6	3	4	0	0
Biscuits	5	4	1	1	0	0	1	0
Chips	5	5	2	2	0	1	1	0
Breakfast cereal	5	2	2	3	0	1	1	1
Sweet corn	6	0	5	5	0	0	3	0
baby milk	2	2	0	2	0	2	0	0
Pop corn	1	0	1	1	0	0	0	0
Total	47	18	24	22	5	8	6	1

results were found in a study conducted with processed food sold commercially in Iran (Rabiei et al., 2013). The results were in accordance with the composition of the sample as all maize-based samples were Adh-positive and all soybean-based samples were lectin-positive. Additionally, to determine the specificity of the maize and soybean-specific primers, DNA from tomato, sesame, wheat, peanut, coconut, banana and rice were included in PCR. As expected, the primers did not amplify in the no-maize and soy samples due to the lack of Adh and lectin gene in tomato, coconut, banana and rice.

To assess the presence of genetic modification in food samples, P-35S promoter and NOS terminator were analyzed. The P-35S promoter from CaMV and NOS are the most favorable candidates screening methods and are most frequent promoter and terminator sequences inserted in most GM crops as regulatory genes respectively (Safaei et al., 2019; Aburumman et al., 2020; Ashrafi-Dehkordi et al., 2021). Oraby et al. (2021) suggested that primers P-35S from CAMV can be used in parallel with the primer GT88 targeting the new region of the *CAMV*-35P promoter to strengthen the results. Out of 47 tested samples, 22 showed the presence of CAMV-35S promoter and 5 for the terminator NOS confirmed by the PCR fragment of 80 bp (Figure 2) and 118 bp respectively. The results indicate that soybean and maize positive samples for these two genes are genetically modified. Most of the samples showed low intensity bands, and this may be related with the low amount of DNA yielded or the sensitivity of the conventional PCR. Investigating the efficiency of conventional PCR, Ahatovic et al. (2021) reported 12.3% of tested samples with low band intensity, and the sensitivity of the agarose gel was mentioned as one of the factors affecting the PCR efficiency. Positive result for CaMV 35S promoter in processed foods may indicates a probability of presence of the GM material (Arun et al., 2013; Bak and Emerson, 2019). Although some samples in our study did not amplify with NOS, they have shown an exogenous gene introduced. A similar results were found by Safaei et al. (2019) in a study conducted with genetically modified rice where no sample was positive for the presence of NOS.

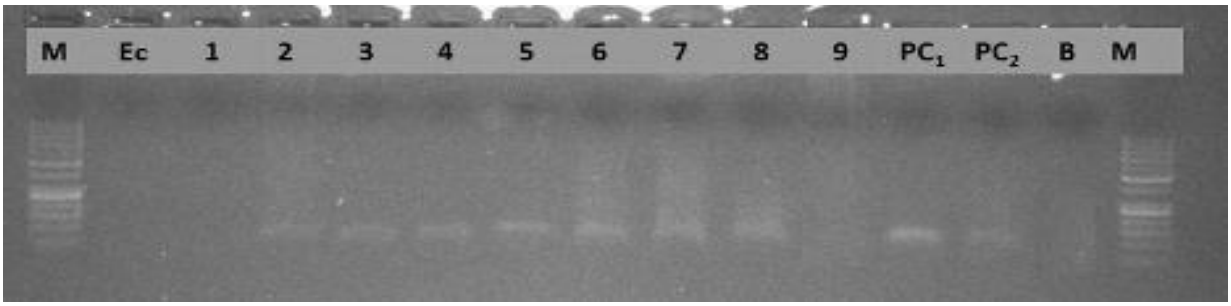

Figure 2. Agarose gel electrophoresis of the CaMV 35S PCR products (80 pb) amplified from genomic DNA. Molecular DNA marker (M); Environmental control (Ec); Lines 1-3 maize flour; Lines 4-6 baby food; Line 7 baby milk; lanes 8-9 biscuit; Mon 863 10% (PC1); GM Maize (PC2); Blank- Mon 863 0% (B).

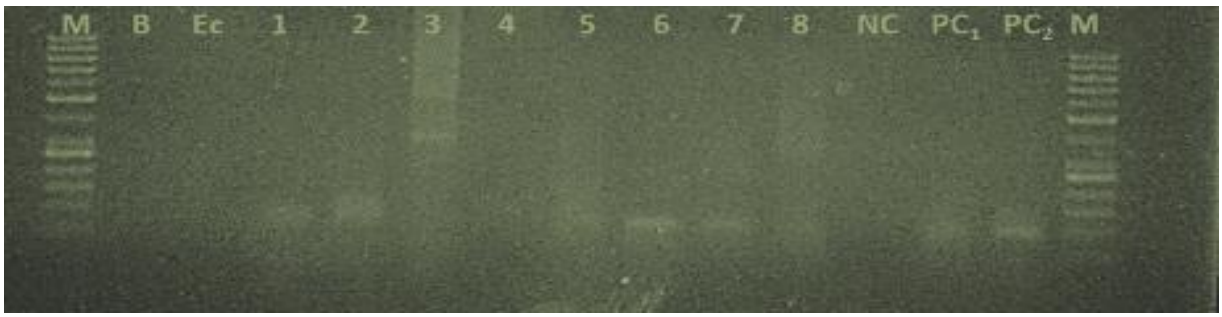

Figure 3. Agarose gel electrophoresis of the Mon 863 PCR products (84 pb) amplified from genomic DNA. Molecular DNA marker (M); Blank- Mon 863 0% (B); Environmental control (Ec); Line 1 chips; Line 2 breakfast cereals; Lines 3-4 maize flour; Line 5 baby milk; Lines 6-7 sweet corns; Line 8 biscuits; RRS 1% (NC); GM Maize (PC1); Mon 863 10% (PC2).

In other study, detection of P35S and NOS in maize and soy processed foods samples revealed that 13 of 23 samples were GM positive (Park et al., 2021).

On the other side, none of the environmental control (corresponding to the extraction control) and Blank reference material (Mon 863 0%) included in the study were positive for the 35S promoter and NOS terminator amplification (Figure 2). As expected, these results demonstrated that there were no cross contamination. Almost 90% of the GM samples detected in our study did not carry any GMO-label in their package. Our results are in line with many other food products studies in which it has been shown that more than 70% of GM food products marketed are not labelled (Ujhelyi et al., 2008; Kaur et al., 2010).

Positive soy and maize samples for P-35S or NOS genes were analysed for specific transgenic events RRS, MON 863 and TC 1507. In total, 22 positive samples where at least one regulatory gene was detected, the RRS gene was detected in 8 samples, MON 863 in 6 samples and TC 1507 in 1 sample indicated that all samples contained GM event specific fragments (Figure 3). From the analyzed samples, baby food meal and baby milk containing soy protein showed more positive results for RRS gene and sweet corns for Mon 863. Similar findings were reported by Erkan and Dastan (2017) in their study, where soy protein and cereals constituted the common GMO-containing products observed. The presence of the RRS, MON 863 and TC 1507 events in samples from Mozambique means that the samples were modified genetically with herbicide tolerance and insect resistance genes introduced, the two most frequent transgenic sequences used in the construction of transgenic soy and maize crops (Datukishvili et al., 2015; Rosculete et al., 2018; Ashrafi-Dehkordi et al., 2021). Safaei et al. (2019) reported similar findings in food products marketed in Iran where it was found that 57 soy food products were GM positive for RRS event and for maize food samples, 40% were positive for Bt11 and 13.3% positive for MON 810 event, proving the presence of GM sequences in their genome. In other study carried out in Brazil, 14 maize flour samples were positive for MON 810, Bt11 and TC 1507 and 10 of the 14 samples also tested positive for NK 603 event (Branquinho et al.,

2013).

Conclusion

The results of the present study showed that the DNA extraction method and the conventional PCR used were efficient for isolation and detection of GMOs in food products. None of the labels on samples of processed foods collected in the Mozambican market reported the presence of GM corn or soy. However, these samples indicated the presence of GM materials in their composition. The results of this study will assist in the implementation of the existing regulation in the country regarding labelling of GMOs in food products and ensure the free choice and protection of the consumers in Mozambique. Although these results are encouraging, the need for real-time quantification (RT-PCR) of current events in the country was clearly demonstrated.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Factors influencing compliance with inspection recommendations in food service establishments: A case study of Mansa Municipality, Zambia

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Inspection reports reflect daily operations of Food Service Establishments (FSE) with indications on levels of compliance with food safety standards and regulations, thus, making them central to the enforcement processes in food safety control systems. While compliance with food safety standards and regulations in FSEs is often viewed by the number of non-compliances or inspection violations cited during inspections, non-compliance with inspection recommendations may be an indication of continued non-compliance to the food safety standards. Using a cross-sectional study design, we assess the factors that influence compliance of FSE with inspection recommendations in Mansa Municipality, Zambia. This involved extraction of inspection process details from inspection reports for FSEs inspected was analyzed, followed by the administration of a questionnaire to FSE managers or owners on management and socio-economic factors. The data collected was subjected to both descriptive and inferential analysis. Importantly, the study results revealed that administrative enforcement, follow-up inspections, and reasonable time limits to make corrections are necessary factors to be considered in inspection processes for food establishments to comply with inspection recommendations. FSE owners compared to assigned managers exert more influence on the establishment's compliance to inspection recommendations when actively involved in the daily operations. Well-operated inspecting institutions and FSE owners play key roles in facilitating FSEs' compliance with inspection recommendations as this ultimately facilitates compliance with food safety standards.

Key words: Compliance, Inspection recommendations, Inspection violation, Food Service Establishment, Foodborne illness.

INTRODUCTION

Regular monitoring of set standards through inspections is central to the enforcement processes in food safety control systems (Mwamakamba et al., 2012). Inspections form the main means of confirming whether a Food Service Establishment (FSE) complies with food safety standards and regulations in its daily operation. Kotsanopoulos and Arvanitoyannis (2017) observe that inspections and quality audit in the food industry evaluate

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management systems assess the condition of premises and products, and confirm legal compliance. According to Powell et al. (2013), the purpose of health inspections in food systems is to continuously assess the practices and processes used by food producers at each step in the production or preparation of food. Inspections can also identify deficiencies for improved food safety in restaurants and training needs for specific restaurants following the violations identified during the inspections (Kwon et al., 2012, 2014). At the same time, evaluation of the inspection reports can give details to the deficiencies in Health Inspectors (Kwon et al., 2014), especially when they fail to identify the critical violations during the inspections. Jones et al. (2004), also note that an effective inspection system should be uniform, consistent, and focused on identifying characteristics known to affect food safety. The British Columbia Ministry of Health (2006), suggests that inspection should also concentrate on the complex food processes, which involve multiple ingredients being assembled or mixed, cooking of potentially hazardous food, holding prepared foods for several hours before service, foods which must be cooled and reheated, as these are the risk practices that are known to cause foodborne illnesses.

Research has shown that critical violations identified in food establishments have the likelihood of causing food-borne illnesses. According to Petran et al. (2012) in a study that tried to relate data collected during routine inspections in Minnesota, USA revealed that overall restaurant evaluation after routine inspections may not be predictive of the likelihood of foodborne illnesses but some of the violations observed during the routine inspection may indicate the likelihood of foodborne illnesses occurring. It has been further observed by Kirandeep (2016) that inspection violations are indications of improper food safety practices, cleanliness, and pest infestations. The type of critical violations cited after each inspection gives particular information on the potential risks of causing food-borne illnesses. The categorization of inspection violations is either critical or non-critical. Critical violations are those food handling practices that are the most common causes of foodborne illness, while non-critical violations include sanitation and maintenance risks where a loss of control would not pose a significant health risk (Nieboer et al., 2015). The inclusion of an inspection violation in the inspection report is, however, dependent on whether the Health Inspector viewed the violation as important to be included in the inspection report and that the violation had the potential of causing foodborne illness (Johnson et al., 2014). It is important to mention that all violations, whether critical or non-critical, cited in an inspection report should be included based on the food safety standards.

The violations identified in foodservice establishments during an inspection indicate poor food handling practices. According to Cseke et al. (2014), items or actions that do not cause an immediate health hazard are classified as lower risk, and these include conditions of surfaces that do not contact food such as floors, walls, ceilings, lighting, and ventilation. While critical items like employee hygiene or storage of potentially hazardous foods are more valid assessments of the risk of an establishment. Therefore, in inspections, more concentration is given to the identification of critical violations which if not controlled may result in food-borne illnesses. Appling et al. (2018), found that some of the critical violations (such as food contact surfaces not being clean to sight and touch or sanitized before use and hand-wash facilities not being stocked with hand cleanser, sanitary towels, or hand drying devices) were more likely to be cited in sporadic *Salmonella* cases. However, Yapp and Fairman (2006), noted that most inspection reports cite non-critical violations.

Risk-based inspections are used in determining food safety risks in a particular Food Service Establishment (FSE). This involves the identification of critical violations that can cause food-borne illnesses (Hoag et al., 2007; Kwon et al., 2014). This is because they act as a means for surveillance of sources of food-borne illnesses as they help categorize food service establishments into high-risk, medium, and low-risk establishments (Hoag et al., 2007). High-risk food establishments are defined as those that perform extensive handling of raw ingredients; use preparation processes that include the cooking, cooling, and reheating of potentially hazardous foods; or use a variety of processes that require the hot and cold holding of potentially hazardous food; or whose food processes include preparation for next day service (British_Columbia-MoH, 2006). When food establishments are categorized according to the food safety risk, it becomes a basis for the frequency with which the food service establishments can be inspected. Thus, food establishments categorized as high risk are expected to be frequently inspected.

In some countries, such as Zambia, it is expected that after an inspection, the Food Service Establishment is served with an informal letter (inspection report) or a statutory notice so that it can refer to the specific violations which need corrective measures to ensure that it fully complies with food safety standards. Non-compliance to inspection report recommendations may indicate a continued non-compliance to general food safety standards. The food safety control system, therefore, depends on the process of inspection violation abatement by food establishments in line with food safety standards (Public Health Act, Cap 295).

In the event where corrective measures are not timely acted upon by the Food Service Establishment (FSE) in the specified time frame indicated in the informal letter, more formal enforcement approaches are taken such as issuance of statutory notices, prosecutions, and closure of premise (Public Health Act, Cap 295, Yapp and Fairman, 2006; Läikkö-Roto et al., 2016). In Zambia, the regulatory framework that outlines food safety standards

includes the Food Safety Act of 2019 of the Laws of Zambia. Other regulations used to regulate food safety management include the Public Health Act, Chapter 295, and the Local Government Act, Chapter 281 of the Laws of Zambia.

On the other hand, several studies on food service establishment inspections have concentrated on factors that measure the Food Service Establishment's compliance to food safety standards and the possible risks of causing foodborne illnesses, particularly gauging the performance of a food service establishment on food safety standards by the number of violations cited during an inspection using scorecards (Irwin et al., 1989; Jones et al., 2004; Phillips et al., 2006; Newbold et al., 2008; Lee, 2013; Leinwand et al., 2017). In addition, some studies conducted have concentrated on the factors that hinder food service establishments from complying with food safety standards and regulations, with particular concentration on the enforcement implications (Yapp and Fairman, 2006; Läikkö-Roto et al., 2015; Kettunen et al., 2018). However, most of these studies have been conducted in countries that implement compliance law enforcement strategies where conformity to food safety regulations is through insuring compliance or by action to prevent potential violations without the necessity to detect, process, and penalize violators. Meanwhile, countries with deterrence law enforcement strategies have to deal with Food Service Establishment's non-compliance to recommendations after inspections or rather detecting violations to enforce food safety in Food Service Establishments (Yapp and Fairman, 2006), to which there is little information on what factors influence the Food Service Establishment's compliance to inspection recommendations.

Inspection of trading premises in Zambia is conducted by Health Inspectors employed by the Ministry of Health and Local Government and Housing. In the period between 2017 and 2018, altogether, a total number of 4,094 inspections conducted on various types of trading premises in Mansa district, with 14 premises reported to have been closed for unsanitary conditions (Mansa DHO, 2018). Despite all the health inspection activities conducted, there has been low compliance to inspection recommendations by food service establishments. It is expected that food service establishments adhere to the inspection recommendations for them to comply with food safety standards. The Health Management Information System (HMIS) reports obtained from Mansa District Health Office (2018), however, indicate that out of the 434 statutory nuisance notices issued in 2018, only 209 (48.15%) were complied with. During the same period, the provincial picture showed that only 28% (1157/4120) were complied with (Luapula Provincial Health Office, 2018). Trends of continued low compliance to statutory notices by trading premises, especially as that of non-compliance of Food Service Establishments to inspection recommendations often increase foodborne diseases. On the other hand, the credibility and purpose of conduction health inspections in Food Service Establishments are reduced (Menachemi et al., 2012).

This research study was designed to assess the factors that influence Food Service Establishments' compliance to inspection recommendations, with a particular focus on socio-economic factors, food service establishment management characteristics, and inspection processes or mechanisms used by enforcement agencies. The specific factors considered in the research study included gender, age, level of education, knowledge of food safety of the FSE manager or owner; location of the FSE, the type or size of business, income, and the type of FSE (restaurant, butchery, or bakery), or premise ownership; administrative enforcement measures instituted by the inspecting institution, follow-up inspections, inspection frequency and time limit given to the Food Service Establishment to take corrective measures.

METHODOLOGY

Data collection

Data collected from inspection reports of 148 Food Service Establishments located in the municipal area for Mansa Municipal Council in Luapula Province of Zambia and the interviewed food service managers or owners were analyzed to establish what factors influenced the compliance of Food Service Establishments with inspection recommendations in Mansa Municipality. The review of inspection reports involved reviewing inspection process details and actions taken within the inspection cycle while taking note of the varying number and type of critical and non-critical violations cited in the subsequent inspection reports in the inspection cycle from the initial inspection. The inspection details and action taken included any administrative enforcement measures instituted by the inspecting institution (notices on closure of premises, withdrawal of licenses, or any other enforcement action taken by the inspecting institution), Follow-up inspections, Number of Inspections, Inspection frequency, and time limit given. This data was collected using a checklist. The food service managers or owners of the Food Service Establishments that had their inspection reports reviewed were then interviewed on the social-economic factors using a structured questionnaire. This included the gender, age, level of education knowledge of food safety of the FSE manager or owner. Other factors included the location, type or size of business, premise ownership, income, and the type of FSE (Restaurant, Butchery, or Bakery).

Data analysis

The data analysis methods used in this study included descriptive and inferential statistical analysis. For categorical variables, firstly, the number and percentages were reported by percentage and the actual number obtained, stratified by whether the Food Service Establishment complied or not with inspection recommendations. To test for any differences in the proportions, either the Chi-squared test or Fisher's exact test was used depending on whether the assumptions of a Chi-squared test are satisfied or not. For continuous variables, the data were tested for normal distribution in a histogram. Then, if the variable follows a normal distribution, the mean and standard deviation were reported stratified by the dependent variable, otherwise, the median and interquartile range

were reported, stratified by whether the Food Service Establishment complied or not with inspection recommendations. To check any differences in the continuous variables, either a t-test or Wilcoxon rank-sum test was used depending on whether the assumptions of a t-test were satisfied or not.

For inferential statistical analysis, bivariate logistic analysis was used to determine the strength of association between each independent variable and the food establishment's compliance to inspection recommendations; and multiple variable logistic regression analysis was used to determine the strength of association between each independent variable and the Food Service Establishment's compliance to inspection recommendations taking into account all other explanatory variables. Furthermore, the machine-led stepwise logistic regression was applied to check the best fitting model that explains the Food Service Establishment's compliance to inspection recommendations cited in the inspection reports.

All statistical tests were set at a 95% confidence level, and at the same time, all analyses were performed using STATA software, version 14.2 SE (Stata Corporation, College Station, TX, USA). Additionally, all research ethics protocols were adhered to, including obtaining the necessary permission from the University of Zambia Biomedical and Research Ethics Committee (UNZABREC), the National Health Research Authority (NHRA), Mansa Municipal Council (MCM), and the individual FSEs that participated in the study.

RESULTS

Demographics of food service establishments

The study subjects included 148 food service establishments; restaurants 132/148 (89.19%), butchery 11/148 (7.43%), and bakery 5/148 (3.38%). Of the Food Service Establishments in the study, 43/148 (29.1%) complied with inspection recommendations, while 105/148 (70.9%) of the FSEs did not comply with inspection recommendations. At the same time, of the FSE's that participated in the study, 24.32% were run by a male manager or owner, and 75.68% of FSE's were run by a female manager or owner.

Descriptive analysis of common inspection violations cited in the inspection reports

The analysis of the inspection reports indicated
that there were more non-critical inspection violations cited in the inspection reports than critical inspection violations. The average number of inspection violations observed per Food Establishment that was inspected was 2.89 inspection violations per inspection conducted. The average number of critical inspection violations cited in the inspection reports was 1.30 inspection violations per inspection; ranging from 0 to 4 inspection violations per inspection. On the other hand, the average number of non-critical inspection violations cited in the inspection reports analyzed was 1.59 inspection violations per inspection conducted and ranged from 0 to 5 inspection violations (Table 1).

Characteristics of Food Service Establishment's compliance with inspection recommendations

The baseline factors influencing FSE's compliance with inspection recommendations are presented as grouped into three including management factors, socio-economic factors, an lastly, inspection processes shown in Tables 2 to 4, respectively.

Management factors influencing compliance to inspection recommendations in Mansa district

Only 21.52% (n=17) of the FSE's whose daily management of the establishment was by the owner of the food establishment complied with inspection recommendations compared to 37.68% (n=26) whose day to day management of the establishment was by a manager; and this difference was statistically significant (17 vs 26; p-value = 0.031). Similarly, there was a significant difference in compliance of FSE's with inspection recommendations among FSE's whose managers or owners have undergone management training and those that have not undergone any management training. Of the Food Service Establishments whose manager or owner had undergone management training to run the food establishment, 57.14% (n=8) complied with the inspection recommendations compared to 26.12% (n=35) that did not undergo any management training (8 vs 35; p-value=0.015).

However, there was no significant difference in the median age of manager or owner of the Food Service Establishments that took part in the study; the median age being 35 (interquartile range 31 - 42) in FSE's that complied with inspection recommendations compared to 37 years (interquartile range 31 - 44) among those FSE's that did not comply with inspection recommendations (35 years vs 37 years; p-value = 0.390). Additionally, there was no significant difference, statistically, between FSE's whose managers or owners were male or female. Of the FSE's that complied with inspection recommendations, 19.44% (n=7) of the FSE's were managed by male FSE managers or owners compared to 32.14% (n=36) that were being managed by female FSE managers or owners (7 male vs 36 female; p-value 0.144). The level of education of the FSE's manager or owner was indicated not to be statistically significant. Of the FSE whose managers or owners who have reached tertiary education, 18.60% (n=8) complied with inspection recommendations compared to 11.63% FSE managers or owners that had gone up to primary education or 69.77% of FSE managers or owners that had gone up to secondary education level.

There was no significant difference in percentage between FSE's that complied with inspection recommendations compared to those that did not comply

Table 1. Common critical and non-critical inspection violations cited in the inspection reports analyzed in the research study.

S/N	Description of inspection violation	No. of FSE violating	% of FSE violating
A	**Analysis of top 5 Critical violations cited in the inspection reports**		
1	Food handlers are medically examined every six months and also restricted from handling food when sick	70	47.30
2	Adequate number of toilets and hand-wash facilities, properly located and designed	29	19.59
3	Safe water source: Availability of sufficient safe water. All water supplied to the food establishment, either from public systems or private wells, must meet WHO drinking water standards	23	15.54
4	Sewage disposal: Food establishments must meet adequate sewage and wastewater disposal requirements	20	13.51
5	Hand-wash facilities are provided with soap and hand towels or disposable tissue	13	8.78
B	**Analysis of top 5 Non-Critical violations cited in the inspection reports**		
1	Floors, walls, and ceilings: floors must be kept clean and free of any build-up of food spills, dirt, and refuse. Walls and ceilings must be kept clean and free from any build-up of food spills, splash, or dirt	62	41.89
2	Premises maintained: the premises in and around a food establishment must be kept in an orderly fashion to prevent attracting and harboring rodents and insects	47	31.76
3	Clean clothes, hair restraints: Food handlers must maintain good clean clothes to prevent contamination of their hands after touching the cloths.	45	30.61
4	FSE has a valid trading and health permit from the Local Authority	21	14.19
5	Garbage and refuse: there must be proper disposal of garbage and refuse in order not to attract, harbor, or act as a breeding place for flies and rodents	18	11.89

concerning food handler food safety training. For instance, of the food handlers that had been trained in food safety handling, 35.0% (n=14) worked for FSE's that complied with inspection recommendations compared to 65.0% (n=26) that worked for the FSE's that did not comply with inspection recommendations. However, the percentage difference was not statistically different (14 vs 26; p-value =0.333). Coupling training and knowledge of food handlers on food safety, the study results indicate that both factors had no effect in influencing overall compliance of the FSE with inspection recommendations.

Socio-economic factors influencing compliance to inspection recommendations by FSE in Mansa district

Only 11.63% (n=5) of the FSE's had a monthly income below K1,500 complied with inspection recommendations compared to 9.30% (n=4) of FSE's that had a monthly income between K1,500 and K4,000, and also compared to 37.21% (n=16) of FSE's that had an income of between ≥ K4, 000 and ≤ K7, 500 and 41.86% (n=18) of FSE's that had a monthly income of K7,500 and above. This difference in the relationship between the FSE's monthly income and the compliance with inspection recommendations was statistically significant (5 vs 4 vs 16 vs 18; p-value = 0.022). At the same time, among the FSE's that had a monthly income of K7,500 and above, 41.86% (n=18) complied with inspection recommendations compared to 32.38% (n=34) that did not comply with inspection recommendations.

However, there was no significant difference in the FSE's that complied with inspection recommendations concerning the type of FSE, location of FSE, premise ownership, or the size of the FSE. Of those FSE's that complied with

Table 2. Baseline characteristics of management factors influencing Food Service Establishment's compliance with inspection recommendations.

Management factors	FSE compliance to inspection recommendation		P-value < 0.05
	Complied (n=43)	Not complied (n=105)	
Manager or owner' sex			
Male	7 (19.44)	29 (80.56)	0.144*
Female	36 (32.14)	76 (67.86)	
manager or owner's age			
Median (Interquartile range)	35 (31 – 42)	37 (31 – 44)	0.390**
Person in-charge			
FSE Owner	17 (21.52)	62 (78.48)	0.031*
FSE manager	26 (37.68)	43 (62.32)	
Level of education			
Primary education	5 (11.63)	17 (16.19)	
Secondary education	30 (69.77)	73 (69.52)	0.643*
Tertiary education	8 (18.60)	15 (14.29)	
Food safety training - manager or owner			
Trained in food safety	14 (31.11)	31 (68.89)	0.700*
Not trained in food safety	29 (28.16)	74 (71.84)	
Knowledge on food safety - manager or owner			
Average	0 (0)	2 (1.35)	
Good	5 (11.63)	11 (10.48)	0.651*
Very good	38 (88.37)	92 (87.62)	
Knowledge on food safety - Food handler			
Average	0 (0)	1 (0.95)	
Good	6 (13.95)	23 (21.90)	0.548***
Very Good	37 (86.05)	81 (77.14)	
Management training			
Trained in managerial skills	8 (57.14)	6 (42.86)	0.015*
Not trained in managerial skills	35 (26.12)	99 (73.88)	
View on Inspectors performance			
Below average	0 (0)	3 (2.86)	
Average	34 (79.07)	82 (78.10)	0.714***
Above average	9 (20.93)	20 (19.05)	
Months of experience			
Median (Interquartile range)	32 (13 – 58)	36 (18 – 64)	0.278**
Food Handler food safety training			
Food handlers trained in food safety	14 (35.00)	26 (65.00)	0.332*
Food handlers not trained in food safety	26 (26.85)	79 (73.15)	

*Chi-squared test; **ManneWhitney test; ***Fisher exact test.

inspection recommendations, 83.72% (n=36) of the FSE's were restaurants compared to 11.63% (n=5) butcheries and 4.65% (n=2) bakeries (36 vs 5 vs 2; p-value = 0.391). Of the FSE's that were occupied by the owner of the premise (this is where the owner of the premise was running a Food Service Establishment), 30.77% (n=8) complied with the inspection recommendations compared to 28.69% (n=35) that were

Table 3. Baseline characteristics of socio-economic factors influencing Food Service Establishment's compliance with inspection recommendations.

Socio-economic factors	FSE compliance to inspection recommendation		P-value < 0.05
	Complied n=43	Not complied n=105	
Type of FSE			
Restaurant	36 (83.72)	96 (91.43)	
Butchery	5 (11.63)	6 (5.71)	0.391***
Bakery	2 (4.65)	3 (2.86)	
Location of FSE			
Town Centre	19 (44.19)	37 (35.24)	
Market (low density residential area)	1 (2.33)	2 (1.90)	0.244***
Market (medium density residential area)	20 (46.51)	46 (43.81)	
Market (high density residential area)	3 (6.98)	20 (19.05)	
Premise Ownership			
Owner occupying premise	8 (30.77)	18 (69.23)	0.832*
Tenant occupying the premise	35 (28.69)	87 (71.31)	
Size of business			
Micro enterprises	39 (90.70)	99 (94.29)	
Small enterprises	3 (6.98)	6 (5.71)	0.295***
Medium enterprises	1 (2.33)	0 (0)	
FSE's Monthly Income			
Below K1,500	5 (11.63)	6 (5.71)	
K1,500 to K3,999	4 (9.30)	33 (31.43)	0.022***
K4,000 to K7,499	16 (37.21)	32 (30.48)	
K7,500 and above	18 (41.86)	34 (32.38)	

*Chi-squared test; **ManneWhitney test; ***Fisher exact test.

occupied by a tenant (8 vs 35; p-value = 0.816).

Inspection process factors influencing compliance to inspection recommendations by FSE in Mansa district

It was noted that of the Food Service Establishments that complied with inspection recommendations, 69.44% (n=25) of FSEs had received follow-up inspections to verify if the FSE had made corrective actions on the inspection violations compared to 16.07% (n=18) of the FSE that did not receive follow-up inspections of their premises; and this difference is statistically significant (25 vs 18; p-value <0.000). At the same time, there was a significant difference between those FSE's that complied with inspection recommendations and those that did not comply with the various variables relating to whether the inspecting institution subjected administrative enforcementmeasures against those FSE's that did not make correct the inspection violations cited in the initial inspection. For instance, 39.53% (n=17) of FSE's whose inspecting institution did not institute administrative enforcement measures against complied with inspection recommendations compared to 94.29% (n=99) of the FSE's that did not comply with the inspection recommendations (17 vs 99; p-value <0.000). Of the FSE's that were issued with closure notices as an administrative enforcement measure taken by the inspecting institution, 18.60% (n=8) complied with inspection recommendation compared to 3.81% (n=4) that did not comply with the inspection recommendations; and this difference amongst the group was statistically significant (8 vs 4; p-value <0.000). Lastly, of the FSE's that were given a time frame of 24 h to make corrective actions on the inspection violations sited during the initial inspection, 20.93% (n=9) FSE complied with inspection recommendations compared to 47.62% (n=50) of FSE's that did not comply with inspection recommendations; and this difference is statistically significant (9 vs 47; p-value <0.000).

Factors influencing the compliance of food service establishment with inspection recommendations cited in the inspection report

Some factors remained statistically significant both as

Table 4. Baseline characteristics of factors relating to inspection processes influencing FSE's compliance with inspection recommendations.

S/N	Factors relating to inspection processes	FSE compliance to inspection recommendation		P-value < 0.05
		Complied (n=43)	Not complied (n=105)	
1	**Follow-up Inspections**			
	Follow-up inspections done	25 (69.44)	11 (30.56)	0.000*
	No follow-up inspections done	18 (16.07)	94 (83.93)	
2	**Number of follow-up inspections**			
	Median (Interquartile range)	1 (0 - 1)	0 (0 - 0)	0.000**
3	**Time limit given**			
	Immediately (within 24hrs)	9 (20.93)	50 (47.62)	0.000*
	2 - 7 days	7 (16.28)	32 (30.48)	
	8 - 14 days	0 (0)	0 (0)	
	15 - 28 days	0 (0)	0 (0)	
	No time specified	11 (25.58)	22 (20.95)	
	Not required	16 (37.21)	1 (0.95)	
4	**Frequency of inspections/per year**			
	Once/year	12 (27.91)	34 (32.38)	0.190*
	Twice/year	13 (30.23)	42 (40.00)	
	Three times/year	12 (27.91)	24 (22.86)	
	Four times and above/year	6 (13.95)	5 (4.76)	
5	**Inspection report generation**			
	Report submitted after each inspection	37 (35.24)	68 (64.76)	0.010*
	Report not submitted after each inspection	6 (13.95)	37 (86.05)	
6	**Administrative enforcement measures**			
	Not necessary for administrative enforcement action	17 (39.53)	1 (0.95)	0.000*
	No administrative enforcement action taken	16 (37.21)	99 (94.29)	
	Penalty charged	2 (4.65)	1 (0.95)	
	Premise closed	8 (18.60)	4 (3.81)	
	Premise closed and penalty charged	0 (0)	0 (0)	

*Chi-squared test; **ManneWhitney test; ***Fisher exact test.

crude and adjusted levels; while others gained their statistical significance while taking into account the other factors (Table 5). Among the management factors assessed to whether they influenced the Food Service Establishment's compliance with inspection recommendations, only factors including the manager or owner's gender, the person in charge of the daily operation of the FSE, and management training indicated influencing FSE's compliance with inspection recommendations after adjusting the odds ratios. Whilst the majority of socio-economic factors indicated not influencing FSE's compliance with inspection recommendations after adjusting the odds ratios except for the FSE's monthly income. Food Service Establishments that earned a monthly income between K1,500 and K4,000, concerning those FSE's that earned a monthly income below K1,500, indicated to influence the FSE's compliance with inspection recommendations. Inspection processes that remained influential to the FSE's compliance with inspection recommendations even after adjusting the odds ratio include that of follow–up inspections and administrative enforcement measures taken by the inspecting institution. While factors whose variables had indicated to influence the FSE's compliance with inspection recommendations under crude odds ratios such as the number of follow-up inspections conducted by the inspecting institution, time limit given to the FSE to take corrective measures against the inspection recommendations, and inspection report generation indicated not to influence the FSE's compliance with inspection recommendations after adjusting the odds ratios.

Table 5. Crude and adjusted odds ratio of factors influencing FSE's compliance with inspection recommendations.

S/N	Factor	Crude				Adjusted			
		Odds ratio	95% CI		P-value < 0.05	Odds ratio	95% CI		P-value < 0.05
A	**Food service establishment management factors**								
1	**Manager or owner' sex**								
	Male	Ref.	n/a	n/a	n/a	Ref.	n/a	n/a	n/a
	Female	0.510	0.203	1.273	0.149	0.105	0.017	0.643	0.015
2	**Manager or owner's age**								
	Age	1.020	0.981	1.060	0.318				
3	**Person in-charge**								
	FSE Owner	Ref.	n/a	n/a	n/a	Ref.	n/a	n/a	n/a
	FSE manager	0.453	0.220	0.936	0.032	0.248	0.058	1.042	0.057
4	**Level of education**								
	Primary	Ref.	n/a	n/a	n/a				
	Secondary	0.716	0.242	2.116	0.545				
	Tertiary	0.551	0.148	2.055	0.375				
5	**Food safety training: Manager or owner**								
	Trained in food safety	Ref.	n/a	n/a	n/a				
	Not trained in food safety	1.152	0.537	2.472	0.716				
6	**Knowledge on food safety – Manager or owner**								
	Average	1*	-	-	-				
	Good	0.909	0.296	2.792	0.867				
	Very good	1**	-	-	-				
7	**Management training**								
	Trained in managerial skills	Ref.	n/a	n/a	n/a	Ref.	n/a	n/a	n/a
	Not trained in managerial skills	3.771	1.223	11.634	0.021	5.444	1.176	25.201	0.030
8	**View on inspectors performance**								
	Below average	1*	-	-	-				
	Average	1.085	0.449	2.623	0.856				
	Above average	1**	-	-	-				
9	**Months of experience**								
	Experience	1.001	0.991	1.011	0.842				

Table 5. Contd.

10	**Food handlers food safety training**								
	Food handlers trained in food safety	Ref.	n/a	n/a	n/a				
	Food handlers not trained in food safety	1.467	0.675	3.189	0.334				
B	**Socio-economic factors**								
1	**Type of FSE**								
	Restaurant	Ref.	n/a	n/a	n/a				
	Butchery	0.45	0.129	1.566	0.209				
	Bakery	0.563	0.090	3.506	0.538				
2	**Location of FSE**								
	Town Centre (CBD)	Ref.	n/a	n/a	n/a				
	Market (low density residential area)	1.027	0.874	12.062	0.983				
	Market (medium density residential area)	1.181	0.551	2.532	0.669				
	Market (high density residential area)	3.423	0.902	12.991	0.071				
3	**Premise ownership**								
	Owner occupying premise	Ref.	n/a	n/a	n/a				
	Tenant occupying premise	1.105	0.440	2.774	0.832				
4	**Size of business**								
	Micro enterprise	Ref.	n/a	n/a	n/a				
	Small enterprise	0.788	0.188	3.307	0.745				
	Medium enterprise	1*	-	-	-				
5	**FSE's monthly income**								
	Below K1,500	Ref.	n/a	n/a	n/a				
	K1,500 to K3,999	6.875	1.421	33.261	0.017				
	K4,000 to K7,499	1.667	0.441	6.301	0.452				
	K7,500 and above	1.574	0.423	5.876	0.500				
C	**Factors relating to inspection processes**								
1	**Follow-up inspections**								
	Follow-up inspections done	Ref.	n/a	n/a	n/a	Ref.	n/a	n/a	n/a
	No follow-up inspections done	11.869	4.972	28.334	0.000	112.135	18.744	670.83	0.000
2	**Number of follow-up inspections**								
	# of inspections	0.229	0.116	0.452	0.000				

Table 5. Contd.

3	**Time limit given**							
	Immediately (within 24 hrs)	Ref.	n/a	n/a	n/a	Ref.	n/a	n/a	n/a
	2 - 7 days	0.823	0.279	2.430	0.724	0.967	0.163	5.745	0.970
	No time specified	0.360	0.131	0.992	0.048	0.472	0.059	3.754	0.478
	Not required	0.011	0.001	0.096	0.000	0.020	0.0007	0.707	0.031
4	**Frequency of inspections/per year**								
	Once/year	Ref.	n/a	n/a	n/a				
	Twice/year	1.140	0.461	2.820	0.776				
	Three times/year	0.706	0.271	1.836	0.475				
	Four times and above	0.294	0.076	1.143	0.077				
5	**Inspection report generation**								
	Report submitted after each inspection	Ref.	n/a	n/a	n/a				
	Report not submitted after each inspection	3.356	1.130	8.685	0.013				
6	**Administrative enforcement measures**								
	Not necessary for administrative enforcement	Ref.	n/a	n/a	n/a	Ref.	n/a	n/a	n/a
	No administrative enforcement action taken	100.0	12.477	801.49	0.000	40.486	2.034	806	0.015
	Penalty charged	17.0	0.552	523.79	0.105	44.552	0.552	3595.5	0.090
	Premise closed	6.375	0.570	71.274	0.133	22.353	0.673	742.48	0.082

In the final model, the lack of conducting follow-up inspections to verify if the FSE had complied with the inspection recommendation and whether the inspecting institution took administrative enforcement measures against the FSE or not was seen to be associated with non-compliance with inspection recommendations cited in the inspection report by the FSE. Meanwhile, factors such as gender of FSE manager or owner, the person responsible for the daily management of FSE, and the time limit set for the FSE to make corrective actions were associated with enhancing the FSE's chance of complying with inspection recommendations cited in the inspection report.

The odds of non-compliance of FSE's with inspection recommendations cited in the inspection report was 112.135 (95% CI = 18.744 - 670.828; p-value > 0.000) times more in FSE that did not receive follow-up inspections to verify if the FSE had made corrective actions on the inspection recommendations cited in initial inspection than in FSE's that received follow-up inspection. Similarly, the odds of FSE's non-compliance with inspection recommendations in FSE's managed or owned by female managers or owners were 0.105 times less than in FSE's that were managed by male FSE managers or owners (95% CI = 0.017 - 0.643; p-value = 0.015). The odds of FSE's non-compliance with inspection recommendations in FSE's that had no necessity to be given time limits (as no inspection violations were cited during the initial inspection) was 0.020 (95% CI = 0.0007 – 0.707; p-value = 0.031) times less than in FSE's that were given a time limit of 24 h (at most) to make corrective actions. The odds of FSE's non-compliance with inspection recommendations cited in the inspections report in FSEs who did not receive any administrative enforcement measures by the inspecting institution was 40.846 (95% CI = 2.034 - 805.996; p-value = 0.015) times more than in FSE's that had no necessity to receive administrative enforcement measures by the inspecting institution, taking into account the other factors. Additionally, the odds of FSE's non-compliance with inspection recommendations in FSE's whose daily management was by the manager for FSE was 0.248 (95% CI = 0.058 - 1.042; p-value =

0.057) times less than in FSE's whose daily management was by the owner of the establishment.

Surprisingly, the association between the closure of a food establishment as an administrative enforcement measure taken by the inspecting institution and the FSE's compliance with inspection recommendations cited in the inspection report was not statistically significant, with reference being compared with FSE's that had no necessity for the inspecting institution to take any administrative enforcement measures against the food establishment. The odds of FSE's non-compliance with inspection recommendations cited in the inspection report in FSE's whose premises were closed to enhance compliance was 22.353 (95% CI = 0.673 - 742.481; p = 0.082) times more than FSE's that had no necessity of taking administrative enforcement measures against them. Additionally, there was an insignificant association between compliance of any trading premise with inspection recommendations and closure of premise and having penalty fees charged against the FSE as an administrative measure taken by the inspecting institution.

Similarly, there was no statistical significance in the following: the associations between penalty charges as administrative enforcement measures taken by inspecting institution and the FSE's compliance with inspection recommendations; the association between the time limit of 2 to 7 days of which the FSE is to make corrective actions and the FSE's compliance with inspection recommendations; and that of the association between no time limit given or specified in the inspection report when the FSE is required to take corrective measures against the inspection violations cited in the inspection report and the FSE's compliance with the inspection recommendations.

DISCUSSION

Of the factors reviewed in this study, the factors that influenced compliance of FSE's with inspection recommendations in Mansa district in the period between 2018 and 2019 include FSE manager or owner's gender; person responsible for the day-to-day management of the FSE; whether or not FSE received follow-up inspection; time limit set for the FSE to take corrective actions against the inspection recommendations cited in the inspection report; and administrative enforcement measures taken by inspecting institution. Kotsanopoulos and Arvanitoyannis (2017), noted that the mechanism of conducting inspections is meant to verify as to whether the premise being inspected is compliant with food safety principles, national food safety policies, and law. Thus compliance of the inspected Food Service Establishment (FSE) with the inspection recommendations completes the inspection cycle while giving an assurance that the FSE has fully complied with food safety principles and regulations. Our discussion concerning the findings of the study will be focused on the following.

Compliance levels of food service establishment's with inspection recommendations

The results of the study showed that the prevalence of FSE's compliance with inspection recommendations was low. The results indicated that the prevalence of FSE's compliance with inspection recommendations was 29.1%. This finding is consistent but slightly lower than the quarterly environmental health HMIS records of 48.15% compliance of trading premises with inspection reports issued to them (Mansa DHO, 2018); while during the same period, the Provincial Health Office (2018) HMIS record on compliance of trading premises with inspection reports was 28%. In my view, the low prevalence rate for FSE compliance with inspection recommendations may have reflective implications such as having continued unhygienic conditions and standards in the FSEs that do not comply, loss of economic value of FSEs, unreliable inspection systems, and low expectations from the general public.

Inspection reports

The study results showed that the inspection violations cited in the inspection reports analyzed indicated that health inspectors had no structured inspection template that had a risk-based approach in which a wide range of food safety principles would be checked during the inspection. The approach of inspection reporting being used is where the inspector listed the findings and recommendations and this would result in the inspector not checking on compliance of the FSE on of the key food safety standards as the inspector is not properly guided on what to check for when conducting the inspection. While acknowledging the fact that there could be several factors that may influence the likelihood of writing down the inspection violations as noted in a study conducted in Indiana, United States of America (USA) by Johnson et al. (2014), it can be noted by the frequency of the inspection violations cited in the reports that inspectors tend to check for the same things over and over each time they went for inspections. A study conducted in Finland by Läikkö-Roto et al. (2015), revealed that the use of properly-outlined templates for inspections reports increased the number of inspected items and the number of inspection violations cited. The study results also confirm the findings in a study by Mulat (2006), that indicated that most inspections conducted in Zambia were not focused. The analysis of the inspection reports suggests that most health inspectors make use of visual inspections to cite the violations recorded in the inspection report, with the implication that their recommendations are not aided by any laboratory

investigations. Thus, knowing that there is a possibility that the inspectors may not have inspected some of the critical items, questions the FSE's compliance to food safety standards and regulations.

Food service establishment management factors

The study results showed that FSE's run by female FSE managers or owners were more likely to comply with inspection recommendations than male FSE managers or owners. The contrast between males and female FSE managers or owners was also noted in the number of females against females that ventured into setting up or getting employed in the Food Service Establishments (FSEs). There are more females in the foodservice business in Mansa Municipality than males (that is about 24% males against 75% females).

Dudeja and Singh (2016), suggest that both the FSE manager and owner are supposed to ensure that the food establishment is following all the food safety guidelines and principles. This may be different when we are considering the FSE's compliance with inspection recommendations after the food establishment has been inspected. The results of this study showed that Food Service Establishments whose daily operations are managed by the owner of the FSE business are more likely to comply with inspection recommendations than those managed by the manager or any other employee. This may complement the idea that the FSE owner may be always the person to make a decision and source money to make corrective actions. However, the need for both the manager and the owner to ensure that the inspection recommendations are complied with is important as it facilitates the improvement of the establishment's outlook and also increases customer confidence (Arendt et al., 2014); and at the same time reduce the chances for the inspecting institution from taking administrative actions.

The results in this study showed that Food Service Establishment's whose manager or owner had undergone management training were more likely to comply with inspection recommendations than FSE's whose managers or owners had not undergone management training to run an FSE. The results complement the results of a study conducted in Ohio, USA by Kassa et al. (2010) that showed that FSE's that had certified or trained FSE managers had low critical violations after inspections compared to those FSE's that had no trained or certified managers. This implies that FSE's whose manager or owner has undergone management training to run an FSE may not only have lower inspection violations but also strive to comply with the inspection recommendations.

In this study, food safety training of food handlers and FSE managers or knowing food safety principles, as well as the education level of the FSE manager or owner, had no significant influence on the FSE's compliance with inspection recommendations cited in the inspection report. This may be because food safety training or knowing food safety principles may influence the number of critical and non-critical violations observed in the food establishment (Mathias et al., 1995), as the trained manager or owner will be able to follow the food safety principles. Effective food safety training increases the likelihood that safe working practices are carried out at all times (Seaman and Eves, 2006). The study results are also different from those found in a study done in Chinsali, Zambia by Makombe et al. (2017), who in his study found that education levels of secondary and tertiary were in a better position to make proper decisions on food handling of food. The reason for the results may be because compliance to inspection recommendations is an aftermath of initial inspections and thus factors such as knowledge of food safety principles nor food safety training, education level, all of which only affect the outcome of the initial inspection.

Socio-economic factors

The study results indicated that the majority of socio-economic factors assessed in the study had no significant influence on the FSE's compliance with inspection recommendations except for the FSE's monthly income. Specific references are given on socio-economic characteristics such as the type of FSE (whether restaurant, bakery, or butchery), the location of the FSE, and whether the owner of the premise was the one operating the food establishment, did not influence the FSE's compliance with inspection recommendations. This particular finding is consistent with other studies. A study by Yapp and Fairman (2006) found that small businesses are more likely to choose partial compliance or non-compliance than large businesses, with the lack of money being one of the factors observed as they tend to focus on business survival than compliance. It is, however not consistent with findings of a study conducted in Alabama, the USA by Menachemi et al. (2012), who observed that certain characteristics of restaurants were associated with particular types of inspection violations. At the same time, owing to the fact as observed earlier in the discussion that inspections conducted in Zambia were not focused and had no risk basis, is an indication that certain FSE characteristics such location of FSE or type of FSE would the affect the type of inspection violations cited and not influence the FSE's compliance with inspection recommendations.

Inspection process factors

The study results reveal that the FSE's that the inspecting institution followed up after the initial inspection to verify

whether the FSE had made corrective actions within the specific time frame stated in the inspection report was likely to comply with inspection recommendations than those FSE's that the inspecting institution did follow – up. The study also revealed that administrative enforcement measures taken by the inspecting institution influenced the FSE's compliance with inspection recommendations. Foodservice establishments that are issued with a closure notice or were issued with a penalty charge fee were more likely to comply with inspections than those FSE's that the inspecting institution did not take any administrative enforcement measure against. This result, however, was not statistically significant. A study by Läikkö-Roto et al. (2015) found that the strictness of the actions taken by the inspectors depended on the nature of the inspection violations and often was strengthened when the inspector noticed that the first enforcement actions were not effective. The authors also observed that the correction of the inspection violations was verified always. Thus without follow-up inspections being conducted, the FSE tends to take their time in correcting the inspection violations observed during the initial inspection.

The time limits for correcting the inspection violations are critical for conducting follow-up inspections and administrative enforcement actions. Läikkö-Roto et al. (2015), found that the more often the inspectors set time limits for performing the corrections, the more often they also used stronger actions since the first actions proved ineffective. This implies that time limits for the FSE to perform corrections on the inspection violations would tell the inspector when to make a follow–up inspection. If repeated inspection violations are recorded during the follow–up inspection, then the inspector may need to take administrative enforcement actions. The recently enacted Food Safety Act of 2019 of the Laws of Zambia detects that a certificate of compliance is to be given to all food establishments that comply with the recommendations cited in the inspection report. Hence, the inspecting institution is obliged to conduct the necessary follow–up inspection before they can certify the food establishment as being fully compliant with the food safety standards. The Public Health Act, CAP 295 of the Laws of Zambia also, detects that following several follow–up inspections conducted, legal or administrative enforcement are taken on the food establishment that fails to take corrective actions against the inspection violations cited in the inspection report with the specified time limit (Public Health Act, Cap 295). This also requires that an inspection report is written always and given to the food establishment as reference for having inspected the premise and having specified the time limit the food establishment was to make corrections against the inspection recommendations (Läikkö-Roto et al., 2015). In line with the above literature, the study results showed that FSE's that were given a specific time limit through which they were to make corrections against the inspection recommendations were more likely to comply with inspection recommendations. The results also indicated that FSE's that received inspection reports each time the food establishment was inspected were more likely to comply with inspection recommendations, though the finding was not statistically significant.

Conclusion

The study had sought to establish the factors that influence the compliance of FSE's with inspection recommendations in Mansa Municipality in 2018 and 2019. The level of compliance of Food Service Establishments to inspection recommendations stood at 29.1%. The study results clearly show that unlike the full initial model developed in the conceptual framework, factors including FSE manager or owner's gender; person responsible for the day-to-day management of the FSE; the monthly income for the FSE; whether or not FSE received follow-up inspection; and administrative enforcement measures are taken by inspecting institution influenced the compliance of FSE with inspection recommendations in Mansa Municipality.

It can thus be noted that throughout the inspection processes, factors such as food safety and management training of FSE managers and food handlers, frequency of inspections, and FSE's manager's level of education may influence the FSE's compliance with food safety standards. While, factors such as inspection follow-ups, administrative enforcement measures, the time limit specified for the FSE to take corrective actions against the inspection violations cited in the inspection reports influence the FSE's compliance with inspection recommendations and ultimately results in having the FSE fully comply with food safety standards.

Inspecting institutions and Food Service Establishment owners, therefore, play key roles in facilitating Food Service Establishments' compliance with inspection recommendations as this ultimately facilitates compliance with food safety standards.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Improving the nutritional value of conventional food with underutilized leafy vegetables - consumers' acceptance of combining porridge with cowpea leaf powder

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Reaching the second UN Sustainable Development Goal requires improving the nutritional value of food products and dietary diversity. Simultaneously, recent research highlights the importance of processing highly nutritious but underutilized African leafy vegetables (ALV) for lowering post-harvest losses and bridging off-season gaps. Combining both goals, it seems promising to utilize neglected ALV for enhancing conventional food items that are already well accepted in consumer diets but low in nutritional value. Therefore, this study analyzes consumer demand for maize (*Zea mays* L.) and millet (*Eleusine coracana (L.) Gaertn)* porridges combined with cowpea leaf powder (*Vigna unguiculata* L.Walp) (CLP) in Kayunga, Uganda. The study relies on combining sensory analysis with a binding Becker-DeGroot-Marschak auction to analyze consumer demand. Results show that consumer acceptance of CLP-enhanced porridges is predominantly shaped by sensory perception ($p < 0.05$). Although adding CLP lowers consumers' sensory appreciation, the study still identifies a reasonably large group of consumers, nearly 50% of the participants, who valued CLP-enhanced porridges as much as plain ones. This justifies the conclusion that adding CLP is not without risks but is accepted among many consumers and can thus help to promote the consumption of locally available plants. For future product development, we recommend that priority is given to sensory attributes, and special focus is placed on consumers who barely incorporate fresh vegetables into their diets.

Key words: African leafy vegetables, Uganda, willingness to pay, sensory analysis, porridge.

INTRODUCTION

Micronutrient deficiencies in East Africa remain worrisome. More than 30% of the population suffers from an insufficient intake of vitamins and minerals (FAO, 2020). Recently, researchers worldwide have acknowledged the importance of micronutrient supply, suggesting the relevance of dietary quality instead of plain caloric intake (Miller et al., 2020). Inadequate dietary quality is among the primary causes of a wide number of health issues ranging from cardiovascular diseases to diabetes and death. Poor dietary quality

frequently corresponds with low intake of fruits and vegetables, which is among the leading dietary risk factor (GBD 2017 Diet Collaborators, 2019). Significant challenges for dietary quality, especially in the form of adequate dietary diversity, often arise due to insufficient accessibility that disproportionately affects less-developed parts of the world (FAO, 2020). Furthermore, the globally recognized nutrition transition caused diets to shift toward processed foods (Reardon et al., 2021). Since processed food products are often rich in sugar and salt and low in nutrients (Reardon et al., 2021), this shift has induced severe health challenges such as obesity.

Against this backdrop, research needs to highlight pathways for product development towards more nutrient-rich food items that consumers can add to their diets, thereby increasing both the nutritional value of foods consumed and the diversity of their diets. In order to achieve these goals, the relevant food items need to be accessible and affordable, and feature the main qualities consumers' desire, such as quick and easy preparation. Above all, the food items must have attractive sensory characteristics, as nutritional interventions in food are only promising if consumers accept the foods sensory characteristics (Boateng et al., 2019). This is why it is especially promising to create nutrient-rich food items by enhancing conventional products with more nutrient rich components.

The research presented in this paper reflected this approach. It addressed both nutritional quality and dietary diversity, and analyzed the potential of enhancing consumers' diets through newly developed food items based on enhancement with locally available but underutilized African Leafy Vegetables (ALV). So far, hundreds of ALV grown throughout Africa have gained little attention, despite their excellent nutritional value (Aworh, 2018). Recent literature, however, has highlighted the potential of ALV in addressing micronutrient deficiencies (Maseko et al., 2019). Ochieng et al. (2018) have found that increases in promotion and demand of ALV in a given community increase dietary diversity for women and children under the age of five years. What is more, ALV are valued for their better resistance to pests, diseases, and harsh weather conditions and are often the cheapest source of essential vitamins and minerals, as compared to exotic crops (Aworh, 2018; Bua and Onang, 2017).

It is mostly the lack of awareness of health benefits, lack of knowledge of preparation techniques, and off-season gaps that impede sufficient utilization (Bua and Onang, 2017). Short shelf-lives of only up to two days constitute additional challenges, leading to farmers experiencing losses between 10 and 50 % of their harvest (Gogo et al., 2018). This aspect, however, makes the approach of enhancing conventional food items with ALV components appear even more promising. Such enhancement, contrary to direct marketing of recently harvested ALV, would imply the use of ALV components in more durable conditions (e.g., dried or pulverized). Thus, the utilization of locally available ALV in conventional food products would not only improve the nutritional value of the food items consumed, but also would help reduce post-harvest losses. Yet, evidence of consumers' perception of and preferences for conventional products enhanced with ALV in East Africa is still scarce.

Barugahara et al. (2015), however, found that fermented millet porridge combined with *Moringa oleifera* leaves (Lam.) (part of the ALV family) was accepted among children and mothers in Western Uganda and could be part of a solution of tackling malnutrition. In addition, research on attitudes towards healthy foods in similar contexts supports this optimistic claim. De Groote et al. (2020) identified a potential market for improved cereal products in Kenya and Wanyama et al. (2019) found that poor consumers might welcome foods that are micronutrient-fortified or include new types of nutritious ingredients.

Contributing towards closing the research gap on consumers' perception of and preferences for conventional products enhanced with ALV in East Africa, the present study analyzed consumer demand for traditional porridges combined with ALV component of cowpea leaf powder (CLP). The motivation of this study was to test whether combining soft porridge with cowpea leaves could be a practical approach to introducing nutrition-rich vegetables in East African diets, thereby tackling malnutrition by addressing micronutrient deficiencies. The choice of CLP-enhanced porridge builds on two main reasons. First, porridge is an affordable food frequently consumed by the vast majority of the Ugandan rural population. Its preparation is quick and easy. At the same time, porridges are often solely made out of maize or millet, and lack minerals and vitamins (Ndagire et al., 2015). Second, cowpea leaves provide great nutritional value, and are widely available throughout Uganda (Okonya and Maass, 2014). They are rich in minerals and vitamins, and can provide the recommended daily intake of many health essential nutrients, such as iron, calcium, phosphorus, and magnesium (Enyiukwu et al., 2018). Nevertheless, cowpea leaves are being underutilized, with seasonality

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and inadequate post-harvest handling techniques being among the major challenges. Evidence from Kenya shows that while cowpea leaves are consumed during the season in which cowpeas are produced consumption declines during the off-season (Owade et al., 2020). This highlights the importance of preserving cowpea leaves adequately to bridge off-season gaps.

The objectives of the study were: (1) to assess consumers' demand for maize and millet porridges enhanced with CLP relative to plain porridges using willingness to pay (WTP) auction and sensory perception; and (2) to identify factors influencing consumers' acceptance.

CONCEPTUAL FRAMEWORK

At the outset, we consider how porridges enhanced with CLP align to food preferences among the Ugandan rural population in general. Uganda is in an early stage of a dietary transition that will probably result in health implications (Auma et al., 2019). As in other East African rural communities, about 43% of the food consumed is purchased, with processed and ultra-processed foods making up 70% of all purchases (Reardon et al., 2021). Minimally processed foods such as flour, dried fish, or packaged milk are foods with only a little modification, such as cleaning, drying, or grinding. Ultra-processed foods such as canned sodas or cookies are highly processed products with added salt, sugar, or oil (Reardon et al., 2021). Maize and millet porridges are ultra-processed foods with low nutritional value beyond calories. A study on dietary patterns in rural Uganda found that the consumption of processed diets is among the two major dietary habits of middle aged (39 ± 13 years) men and women. This included high consumption of salad dressing, cold cuts, and sweets. A closer look at food groups being consumed showed mean daily servings of cereals, starchy roots, and plantains were highest (Holmes et al., 2018). Kiguli et al. (2019) found that consumers' food choices in rural Eastern Uganda were predominantly based on availability and local accessibility. There was a particular lack of food diversity during the dry season, and people depended on a few staple foods, such as maize flour, daily. Moreover, a study on pre-cooked beans showed that consumers value nutritious products that are quick to prepare (Aseete et al., 2018). Combining conventional porridges with CLP fits into the current demand for more processed and nutritious foods. Adding CLP is an option to increase dietary diversity during the off-season.

METHODS

Study site and participants

The survey aimed to analyze rural consumers' demand for porridge combined with locally available cowpea leaves. The cowpea leaves were freshly bought from open markets in Kampala, dried and ground, and thus minimally processed. Maize and millet powder were bought from supermarkets in Kampala. We obtained research permission and ethical clearance from the Uganda National Council for Science and Technology and the Makerere University School of Health Sciences Institutional Review Board. The survey was conducted in the Kayunga district of Uganda from February to March 2020. The Kayunga district is a rural area that lies in the North Central part of the country. The prevalence of anemia is around 31% for women and 14% for men, with about 30% of women and 12% of men being overweight or obese (Uganda Bureau of Statistics, 2018). Dietary diversity is lower among rural women than men. Their diet comprises of high fat intake along traditional dietary patterns (Auma et al., 2019). Due to their relatively high prevalence of anemia and lower dietary diversity, and because they are often responsible for food preparation, our main interest was women. However, since food is traditionally prepared for the whole family, we did not completely exclude men from the survey. Cowpea leaves are typical in the area of the study site and are predominantly grown on a small scale. We targeted participants at point-of-purchase at open markets in Kayunga Town, Busaana, Kangulumira, and Nazigo that were open on different weekdays. A pilot study was conducted at a different market in the same location to test the setup of the survey. As the markets were some kilometers apart (> 20 km), it is unlikely that the same participant visited different markets and got selected twice. Participants were screened for the following characteristics to participate in the survey: They had to be at least 18 years old, free of diabetes and food sensitivities, responsible for food purchasing decisions in the household, and interested in testing the target products. Approaching participants at open markets allowed us to question many of them easily. We avoided conducting the same study more than once per market. This allowed us to ensure that participants were not interviewed twice and were thus not already informed about the products by friends or family. We used convenience sampling that included if participants had time to take place in the survey. Participants were approached when entering the market. If they did not meet the qualification criteria the next person entering the market was approached. Approximately 30 participants were questioned per market. The questioning per participant, including the sensory analysis and WTP auction took about 20 minutes. Thus, we spent five to six hours at each market. This allowed us to question participants during different day times (morning, noon, afternoon). The drying of the cowpea leaves and thus, preparation of approximately 400 flour bags was time and resource intensive. The availability limited our sample size, which is therefore rather small. However, it is still sufficient for studying preferences for the enriched porridges. In total, 126 people participated in the survey. Due to incomplete questionnaires, we excluded 24 participants from further analysis. Participants agreeing to participate in the survey were informed about their right to leave the survey at any time, asked to give their written consent, and paid 2000 Ugandan shillings (UGX) (4000 UGX = 1 U.S. dollar at the time of the survey) as an expression of our gratitude for their time and to ensure they had the financial means to participate in the WTP experiment.

Products

We asked each participant to taste four different porridges: millet porridge, millet porridge combined with CLP, maize porridge, and maize porridge combined with CLP (Figure 1). The CLP made up 20% of both mixed porridge types, respectively. The rate was defined after running pre-tests on consumer acceptance of different ratios. The products were developed by nutrition specialists of

Figure 1. Four different porridges: Millet porridge (O), Millet porridge mixed with CLP (), Maize porridge (□), Maize porridge mixed with CLP (□).

Makerere University in Kampala, Uganda. Owing to the nutrients found in the CLP namely zinc, vitamin A and iron their consumption is associated with improved satiety, good immunity, proper digestion, and proper eyesight. The porridges were prepared in traditional way each morning by experienced cooks from our team. Specifically, 60 g of each porridge were mixed with 150 ml cold water; 300 ml boiling water were added to the two millet porridges and 400 ml boiling water were added to the two maize porridges. The two millet porridges were boiled for two to three minutes, and the two maize porridges were boiled for 30 minutes. As porridge is preferred sweet in the area, 25 g of sugar were added to each mixture. To keep the porridges warm for consumption, they were stored in thermo flasks.

Sensory analysis

Tents were used to conduct the survey. This allowed us to shield survey participants and gave them the opportunity to sit down and taste the products in quiet. Each participant was questioned by two enumerators to ensure double-blind testing. The first enumerator asked sociodemographic questions and conducted the sensory analysis. Survey participants received approximately 10 g of each cooked porridge in plastic cups. The amount equaled about three normal mouthfuls of the product, which was presumed to be sufficient to rate the sensory attributes. As we labeled each porridge with either a triangle, circle, square, or pentagon, neither the enumerator nor the participant knew which porridge was inside which cup. The order was randomized to avoid first-sample bias. Participants were asked to rate one porridge at a time. They were not allowed to go back and re-taste samples. Sensory characteristics considered included color, aroma, texture in the mouth, taste, and general appearance. Participants were asked to rate each attribute on a five-point Likert scale ranging from 1 = dislike it very much, 2 = dislike it, 3 = neither like nor dislike it, 4 = like it, 5 = like it very much. The five-point Likert scale has been used in previous studies and was demonstrated to be understandable among less educated consumers (De Groote et al., 2018). The answers were immediately entered onto electronic tablets by the enumerators. Participants were asked to rinse their mouths with water after consuming each product.

Willingness to pay

After finishing the sensory analysis, a second enumerator conducted the WTP using Becker-DeGroot-Marschak (BDM) auction. The BDM is non-theoretical, can be performed individually, and can be implemented at open markets. It has already been applied in several studies assessing consumers' WTP in Africa, and has been easily understood by less-educated participants (De Groote et al., 2018, 2020). The four porridges were shown to the participant in dried form, packaged in transparent plastic bags. Each bag contained 60 g of the dry porridge powder. The porridges were presented in the same randomized order and labeled with the same symbols as in the sensory analysis. The order differed among the participants. The participants were asked to state their WTP for each of the products. The enumerator wrote down their statements. To prevent participants from having to buy all four products, the statement for one product only was randomly chosen as binding. Each participant then drew a number from a basket, which was compared to the price stated for the binding product. If the drawn number was below or equal to the WTP indicated by the participant, they had to buy the product at the random price using their own money. If the randomly drawn number was higher than the stated WTP, the participant had no chance to buy the product. The random distribution ranged around the expected WTP for one porridge, thus from number 100 to 1000. The procedure was described to the participants in detail, and follow-up questions had to be answered correctly. The enumerator informed every second participant about the ingredients of the porridges and their nutritional benefits. While the explanation of the plain porridges contained information about their bodybuilding and energy benefits, the explanation of the porridges combined with CLP contained further information about their contributions to good immunity, proper digestion, and proper eyesight. We assumed there are no systematic differences between the two groups, although we found tendencies in the color perception (Supplementary Table 1). After finishing the WTP experiment, participants were questioned on their general consumption and shopping behavior.

Statistical model

We applied structural equation modeling (SEM) using Stata to determine linkages between participant characteristics and their WTP, using maximum likelihood estimation. The SEM connects linear regression and factor analysis and, in general, analyzes variance-covariance structures (Aichholzer, 2017). Further, the model allowed us to use the response variable of one regression as a predictor in another regression. Figure 2 shows an exemplary SEM. Rectangles represent observed variables, and circles containing ϵ represent error terms. Arrows indicate hypothesized direct effect on endogenous variables. The SEM shows the sum of all assumed structural equations:

$$y_1 = \alpha_1 + \gamma_{11} x_1 + \varepsilon_1 \quad (1)$$

$$y_2 = \alpha_2 + \gamma_{21} x_1 + \beta_{12} y_1 + \varepsilon_1 \quad (2)$$

Variable selection

We estimated one SEM for the millet porridges and one for the

Table 1. Results of the factor analysis on sensory perception of the porridges.

Characteristic[1]	Factor loading			
	Millet	CLP_millet	Maize	CLP_maize
Color	0.70	0.70	0.73	0.59
Aroma	0.71	0.84	0.73	0.81
Texture in the mouth	0.62	0.83	0.85	0.81
Taste	0.74	0.86	0.83	0.84
General appearance	0.78	0.86	0.83	0.87
Cronbach's-α	0.74	0.88	0.85	0.84
KMO	0.77	0.84	0.78	0.83

[1]5-point Likert scale ranging from 1 = dislike it very much to 5 = like it very much.

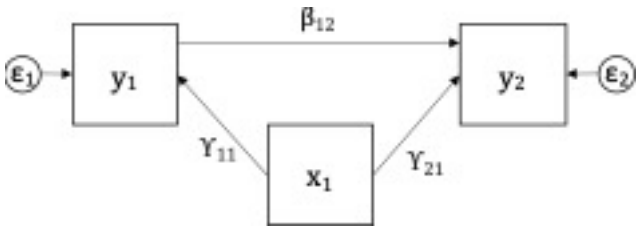

Figure 2. Exemplary SEM.

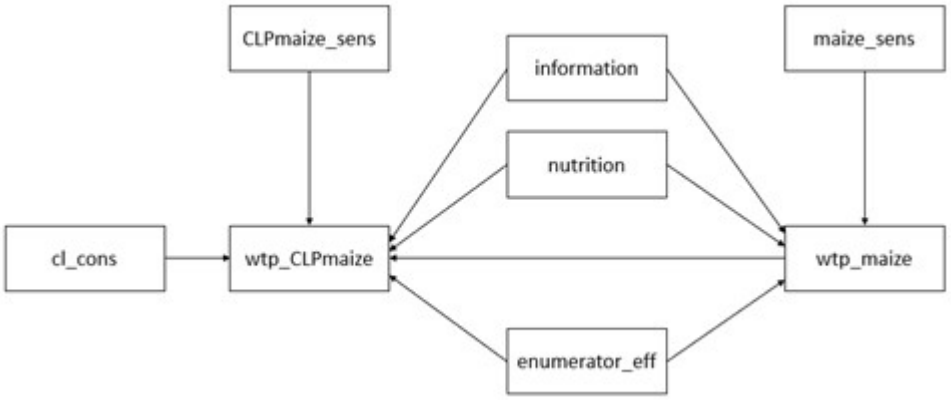

Figure 3. SEM for WTP for maize porridge and maize porridge combined with CLP. cl_cons = frequency of cowpea leaf consumption, sens=sensory perception (factor).

maize porridges. Figure 3 shows the model for the maize porridge. Within both SEMs, we ran two equations, one for the plain porridge and one for the porridge combined with CLP. The plain porridge was also included as a predictor in the regression for the combined porridge. One directly observed variable was used as a predictor, namely whether the participant received additional *information* (binary) about the products. Additionally, we added *frequency of cowpea leaf consumption* in the regressions of the combined porridges. Frequency of cowpea leaf consumption categorically ranged from 0 = never, 1 = 1 to 3 times per month, 2 = 1 to 3 times per week (regularly), 3 = 4 to 7 times per week (frequently). Besides directly observable variables, *nutrition awareness* and the *sensory perception* of each porridge were added as factor variables. To obtain the factors, we ran a principal component factor analysis with varimax rotation. We found that the sensory characteristics of each porridge loaded on one factor, respectively (Table 1). Additionally, we found that six nutrition statements loaded on one factor (Table 2). The sampling adequacy was determined via Bartlett's test and the Kaiser-Meyer-Olkin (KMO) criterion. The internal consistency was determined via Cronbach's-α. KMO values above 0.6 and Cronbach's-α values above 0.5 were considered acceptable. The Cronbach's-α for the sensory characteristic's factors ranged between 0.74 and 0.88, with KMO values ranging between 0.77 and 0.84. The Cronbach's-α for the nutrition awareness factor was

Table 2. Results of the factor analysis on dietary behavior.

Nutrition awareness[1]	Factor loading
I am eating enough vegetables for good health.	0.54
I compare labels to select the most nutritious food.	0.79
I usually look for health information when I buy food products.	0.61
When at the market I look for food that supports the prevention of diseases.	0.64
When at the market I look for food that supports a strong immune system.	0.78
When at the market I look for food that supports good eyesight.	0.60
Cronbach's-α	0.74
KMO	0.77

[1]5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree**.**

0.75 and the KMO 0.78. The enumerator effect was included as a control variable. The error term was robust and clustered at market level. To determine the robustness of the model we reran the calculation including age in years, being female, and education in years.

RESULTS

Participant characteristics

Participants had an average age of about 37 years, were mainly female (72%), and received 7.5 years of formal education (Table 3). On average, participants lived in households comprising of five people. Moreover, 26% of the participants were married and 67% of the participants consumed millet porridge as their main porridge, while the remaining 33% consumed maize porridge as their main porridge. The majority (79%) of the participants had children between 6 and 59 months. Most participants consumed porridge frequently (4 to 7 times per week) or regularly (1 to 3 times per week). This confirms our assumption that porridge is widely consumed in the area and thus, suitable for nutrition intervention. Concerning nutrition awareness, we found a tendency that participants tended to agree with the statements we presented, with mean values above 3. The statements "I am eating enough vegetables for good health" and "When at the market I look for food that supports a strong immune system" received the highest agreement with mean values of 3.96 and 3.92, respectively. The findings suggest that the participants are on average rather conscious about healthy nutrition. This contrasts the assumption that nutrition awareness is low. Still, the results are heterogenous, as up to 30% of the participants rated the statements below 3 "neither like nor dislike it".

Sensory analysis and WTP

The mean sensory scores were highest for the plain millet porridge in all five characteristics (Table 4). These differences were found to be statistically significant, except for the taste in maize. Sensory scores for the porridges combined with CLP received statistically significantly lower scores than their plain porridge counterpart in all characteristics. Millet porridge combined with CLP received statistically significantly higher scores than maize porridge combined with CLP for color and texture in the mouth. Although on average the plain porridges were rated higher than the combined porridges, we found that 40 to 50% of the participants rated the combined porridges at least as high as the plain ones. The mean WTP was highest for plain millet porridge (0.26 US$). This price was significantly higher than the average for the remaining porridges. About 50% of the participants were willing to pay an equally high price for the combined porridges compared to the plain porridges. The distribution of WTP is shown in Supplementary Figure 1.

Structural equation model

Table 5 presents the results obtained from SEM for the millet and maize porridges. Information about the ingredients and health benefits significantly increased participants' WTP for the plain and combined millet porridge. Additionally, participants with a higher nutritional awareness were willing to pay more for the plain millet porridge. Moreover, a higher WTP for both combined porridges is in line with a higher sensory perception and a higher frequency of cowpea leaf consumption of the products. To check for the robustness of the findings, we reran the model with control variables. These variables included age, being female, and education (Supplementary Table 2). We observed the same trends. Based on these findings, we took a deeper look into differences in sociodemographic and sensory perception. We compared these factors between a) participants who were willing to pay a price for the

Table 3. Participant characteristics and consumption frequencies.

Characteristics	Mean	SD	Min.	Max.
Sociodemographic				
Age (years)	36.76	12.73	18	80
No. household members	5.14	2.44	1	14
Years in formal education	7.51	3.36	1	17
Female (%)	72%			
Married (%)	26%			
Millet main porridge consumed (%)	67%			
Children 6 to 59 month (%)	79%			
Porridge consumption				
4 to 7 times per week	60%			
1 to 3 times per week	36%			
1 to 3 times per month	4%			
Cowpea leaf consumption				
4 to 7 times per week	4%			
1 to 3 times per week	50%			
1 to 3 times per month	18%			
Less than once per month/never	28%			
Nutrition awareness[1]				
I am eating enough vegetables for good health	3.96	1.03	1	5
I compare labels to select the most nutritious food	3.28	1.15	1	5
I usually look for health information when I buy food products	3.36	0.97	1	5
When at the market I look for food that supports the prevention of diseases	3.76	1.03	1	5
When at the market I look for food that supports a strong immune system	3.92	0.86	1	5
When at the market I look for food that supports good eyesight	3.72	1.02	1	5
N	102			

[1]5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree.

Table 4. Results of the sensory analysis.

Characteristic	CLP_Millet Mean (SD)	Millet Mean (SD)	% CLP_Millet >= Millet	CLP_Maize Mean (SD)	Maize Mean (SD)	% CLP_Maize >= Maize
Color	3.26^{a} (1.34)	4.26^{b} (1.09)	42	2.62^{c} (1.39)	3.75^{d} (1.33)	45
Aroma	2.93^{a} (1.31)	3.99^{b} (1.13)	41	2.85^{ac} (1.40)	3.72^{bd} (1.32)	51
Texture in the mouth	3.60^{a} (1.30)	4.37^{b} (0.87)	46	3.25^{c} (1.35)	3.95^{d} (1.39)	40
Taste	3.22^{a} (1.45)	4.27^{b} (1.08)	35	3.20^{ac} (1.39)	4.18^{bd} (1.09)	50
General appearance	3.57^{a} (1.19)	4.55^{b} (0.67)	46	3.37^{ac} (1.27)	4.26^{d} (0.99)	46
WTP (US$)	0.22^{a} (0.18)	0.26^{b} (0.19)	48	0.22^{ac} (0.21)	0.23^{abcd} (0.19)	52
N	102	102		102	102	

The letters a,b,c,d reflect significant differences ($p < 0.05$) in a characteristic between the porridges according to Kruskal-Wallis and Duncan-T; % CLP_Millet >= Millet = Percentage of participants who rated the porridge combined with CLP at least as high as the plain porridge.

combined porridges that was at least as high as the price for the respective plain porridge (liker) and b) the ones who were not willing to pay that price (non-liker) (Table 6). In total, 48 participants were likers. The frequency of

Table 5. Results of the structural equation model, coefficients are standardized.

Characteristics	Millet			Maize		
	Coef.	SE[a]	p	Coef.	SE[a]	p
Information	0.183	0.104	0.080*	0.146	0.136	0.281
Nutrition (factor)	0.294	0.086	0.001***	-0.008	0.092	0.932
Sensory perception (factor)	-0.119	0.084	0.155	0.132	0.101	0.192
N = 102						
Characteristics	**Millet porridge combined with CLP**			**Maize porridge combined with CLP**		
	Coef.	SE[a]	p	Coef.	SE[a]	p
wtp_millet	0.572	0.066	0.000***			
wtp_maize				0.434	0.246	0.078*
Freq. cowpea leaf cons.	0.121	0.012	0.000***	0.040	0.012	0.001***
Information	0.094	0.057	0.099*	0.153	0.117	0.191
Nutrition (factor)	-0.083	0.059	0.156	0.090	0.117	0.441
Sensory perception (factor)	0.267	0.055	0.000***	0.237	0.023	0.000***

[a]Standard errors are robust and clustered at market level; *,**and * reflects significance at 10, 5 and 1% respectively.

Table 6. Participant characteristics by WTP.

Characteristics	Liker	Non-liker	P
	Mean (SD)	Mean (SD)	
Female	73%	70%	0.950
No. household members	5.52 (2.56)	4.80 (2.29)	0.140
Years in formal education	7.83 (3.89)	7.22 (2.81)	0.650
Children 6 to 59 months (binary)	90%	70%	0.03**
Frequency cowpea leaf consumption	4.58 (2.07)	3.56 (2.18)	0.01***
Frequency porridge consumption	6.94 (1.19)	6.98 (1.28)	0.710
Nutrition awareness (factor)	-0.1 (1)	0.09 (0.1)	0.34
Color CLP_mill	2.92 (1.49)	2.35 (1.26)	0.06*
Aroma CLP_mill	3.08 (1.35)	2.65 (1.42)	0.110
Texture CLP_mill	3.48 (1.27)	2.94 (1.46)	0.06*
Taste CLP_mill	3.56 (1.22)	2.98 (1.41)	0.04**
General appearance CLP_mill	3.69 (1.03)	3.09 (1.40)	0.03**
Color CLP_maize	3.54 (1.24)	3.02 (1.39)	0.05**
Aroma CLP_maize	3.33 (1.24)	2.57 (1.28)	0.00***
Texture CLP_maize	3.62 (1.38)	2.85 (1.43)	0.01***
Taste CLP_maize	3.94 (1.14)	3.30 (1.37)	0.02**
General appearance CLP_maize	3.90 (1.06)	3.28 (1.23)	0.01***
N	48	54	

*,** and *** Reflects significance at 10, 5 and 1% respectively. Likers are participants who were willing to pay at least as much for porridges combined with CLP as for the plain porridges.

cowpea leaf consumption was significantly higher among this group, and nearly everyone had a child between 6 and 59 months. On average, likers rated all sensory characteristics of both combined porridges higher than non-likers did. This effect was found to be statistically significant for all sensory attributes, except the aroma of the millet combined with CLP.

DISCUSSION

Our study was based on combining traditional porridges with nutrient-rich CLP as a channel to incorporate nutritious vegetables into local diets. Regular consumption of CLP-enhanced porridges will improve dietary diversity as they are rich in micronutrients such as iron, zinc, and

vitamin A. Additionally, processing cowpea leaves into more durable powder can reduce post-harvest losses and bridge off-season gaps. Enhancing traditional porridges with CLP thus appeared to be a promising option; under the condition the product meets consumer demand. First of all, our results confirmed the assumption that porridge is a highly suitable product for enhancing nutrition among the rural population, since porridge is frequently consumed by the survey participants (4 to 7 times per week). Focusing on the core of our research question, our results show that almost half of the participants valued the CLP-enhanced porridges at least as high as the traditional, non-enhanced ones. For this group, the enhanced product can provide an easily accessible and cheap source of important nutrients. However, we also found that combining traditional porridges with CLP lowers sensory appreciation. This leads to the conclusion that the combined porridges will not replace the plain ones but might have a chance as an alternative product on the market. The SEM revealed that sensory perception is an essential factor shaping consumers' WTP for CLP-enhanced porridges. The effect sizes of sensory perception in both combined models were higher than of the remaining three variables.

Sensory perception

The importance of sensory perception was consistent with research on nutritionally enhanced food via biofortification such as quality protein maize. Similar to our findings, De Groote et al. (2014) found that sensory characteristics are among the main drivers of consumers' WTP. Resonating with these findings, another experiment conducted by Wanyama et al. (2019) suggested that ingredients with only minor effects on taste and appearance are seen more positively than ingredients that may change food products more notably. Since consumption of (and thus familiarity with) nutritious and locally available cowpea leaves is low (less than once per week) among most study participants, promoting their utilization constitutes a challenge, but at the same time, it can potentially open a group of potential consumers for the enhanced product. We presume that increasing familiarity with cowpea leaves and African leafy vegetables in general will increase the chance of success for the combined porridges. This presumption is supported by our finding that WTP for the combined porridges increases with higher frequency of cowpea leaf consumption.

Information

With respect to the role of information, we found that giving additional information about the products was partly helpful in improving their demand. Our results show that the WTP for the millet porridges was higher among participants who received further information on their nutritional value. This suggests that participants appreciate knowing about the food they purchase, and confirms results of several other studies conducted in this field (Chowdhury et al., 2011; De Groote et al., 2014; Oparinde et al., 2016). Interestingly, we could not observe the relationship between information and WTP for the maize porridges. We propose that this is due to consumers being aware of the general fact that millet has a higher nutritional value than maize (Orr et al., 2016) and the given information confirmed their believes. The phenomenon of people tending towards information that is in accordance to their beliefs has already been studied in the field of psychology and is often referred to as confirmation bias (Nickerson, 1998). It is our interpretation that giving nutrition information is more persuasive if some form of nutritional perception already exists. In sum, it is interesting that different porridge types are perceived differently, and that distinct ways of promotion might be fruitful for each porridge type. While information campaigns drawing on the benefits of CLP could successfully advertise CLP-enhanced millet porridge, a different approach might be necessary for CLP-enhanced maize porridge which stands to reason if we consider that maize porridge is of low nutritional value. We employed only one mixture ratio of porridge flour and CLP throughout the project. The ratio was based on a pre-study determining the highest amount of CLP that was still considered acceptable. We clearly find a trade-off between nutrition enhancement and the loss of consumer acceptance.

Sensory characteristics

Regarding our control variables we found that younger and less educated participants, who are generally likely to have less cooking knowledge and skills, were especially willing to pay for the plain, non-enhanced porridges, which stresses its suitability to reach vast parts of the population at issue. Plain porridges were, in general, valued even higher among younger and less educated participants, possibly because porridge is quick and easy to prepare and does not require specific cooking skills. The analysis also shows that the plain porridge's sensory perception did not play a significant role in shaping consumers' WTP. We assume that porridge is predominantly consumed for caloric intake and not taste.

Limitations

When assessing our findings, we need to elaborate on

some limitations of the survey conducted. First, it could be promising to add cowpea leaves to other suitable food items, like soups or relishes, where their influence on sensory characteristics could be less dominant. Second, we only studied adults. Since nutrient-poor porridges are often used as a complementary food for children in rural areas (Oladiran and Emmambux, 2020), those children would be an important target group of nutritionally enhanced porridges and should be considered in future studies. Moreover, we analyzed consumers as individuals. Since dietary patterns are significantly shaped by social norms and community practices (Kiguli et al., 2019), it could prove fruitful to add a complementary sociological dimension to this area of research. Third, while the BDM-auction has the benefit of being applicable at the point of purchase, the environment is difficult to control which can influence consumers' responses. Consumers are selected spontaneously and sometimes are in a hurry to finish the study. Although, the experiment was incentive driven to ensure everybody was interested to provide an adequate response and theoretically able to purchase the product, it does not reflect all details of a market purchase. Nevertheless, the method has been applied several times and shown to provide reliable data (De Groote et al., 2014, 2018, 2020). Moreover, the setup of the survey was challenging. Since we conducted the survey in outdoor markets, almost 20% of cases had to be removed from further analysis, as sudden weather changes caused disruption and participants left without finishing the survey. Finally, this resulted in a small sample size, leads to results not being conclusive for minor effects. Thus, we can only show tendencies towards the products and not draw causal relations.

Conclusion

Using sensory analysis and WTP, we assessed the potential of enhancing conventional porridges with CLP as a channel to promote inclusion of locally available, nutritious vegetables into meal plans in East Africa. Descriptive results show that sensory scores are lower among CLP-enhanced porridges, as compared to plain porridges. Still, almost half of the consumers rated them at least equally high in terms of WTP, with the general consumption of fresh cowpea leaves being higher in this group. Thus, CLP-enhanced porridges are unlikely to replace plain ones but could provide an alternative for some consumers. Based on our findings, we make the following recommendations. First, priority in future research should be given to sensory attributes relative to conventional products when enhancing their nutritional value. Second, it is important to find ways to reach consumers who barely, or do not, incorporate fresh vegetables into their dietary habits. Third, education is necessary to sensitize consumers to the importance of diverse and nutrient-rich diets. We expect that a healthy image of the products, which could be generated through information, could be helpful in a mix of marketing measures to promote the products. Fourth, governments should support the utilization of locally available nutritious vegetables to enhance nutrition and lower post-harvest losses simultaneously. This could include supporting training on techniques of processing ALV, as well as education campaigns that raise awareness about dietary quality and nutritional benefits of ALV.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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Supplementary Material

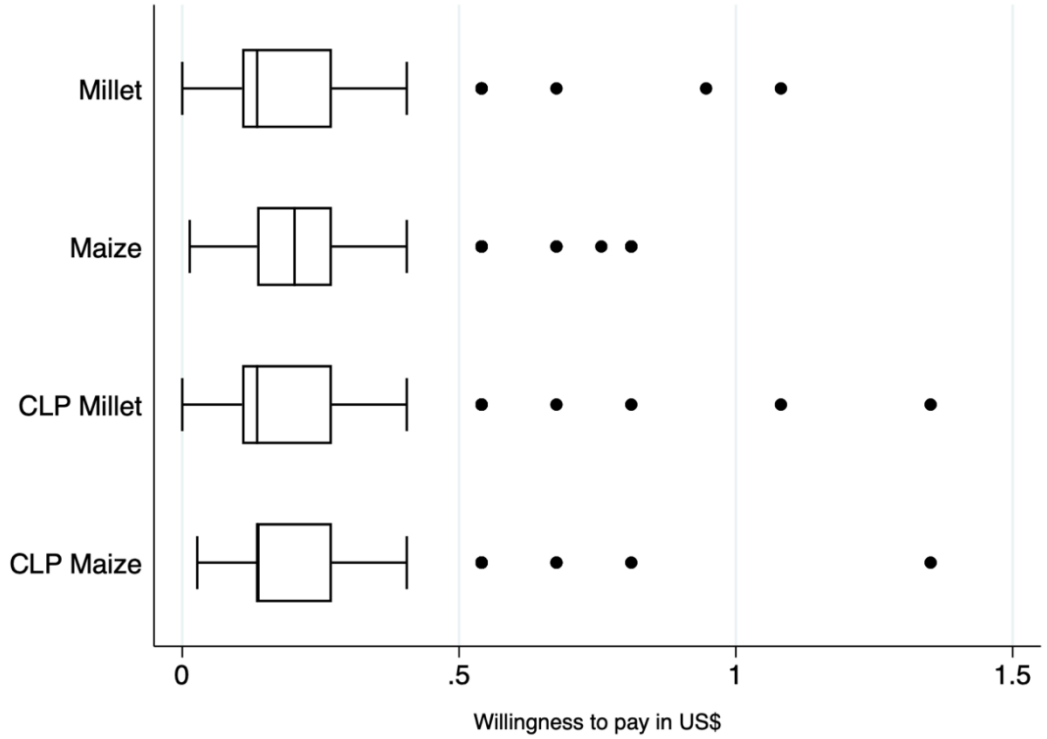
Supplementary Table 1. Participant characteristics, by information.

Characteristics	Information	No information	p
	Mean (SD)	Mean (SD)	
Female (%)	1.75 (0.44)	1.68 (0.47)	0.570
No. household members	4.98 (2.51)	5.30 (2.38)	0.310
Years in formal education	7.04 (3.76)	8.00 (2.84)	0.07*
Children 6 to 59 month (binary)	1.79 (0.41)	1.80 (0.40)	1.000
Frequency cowpea leaf consumption	4.29 (2.08)	3.78 (2.27)	0.390
Frequency porridge consumption	7.02 (1.13)	6.90 (1.34)	0.830
Nutrition awareness (factor)	-0.07 (0.97)	0.07 (1.03)	0.460
Color millet	4.19 (1.21)	4.34 (0.96)	0.670
Aroma millet	3.94 (1.16)	4.04 (1.11)	0.670
Texture millet	4.40 (0.91)	4.34 (0.82)	0.470
Taste millet	4.33 (1.04)	4.22 (1.13)	0.740
General appearance millet	4.52 (0.64)	4.58 (0.70)	0.430
Color maize	3.67 (1.32)	3.84 (1.35)	0.450
Aroma maize	3.62 (1.40)	3.82 (1.24)	0.560
Texture maize	3.87 (1.51)	4.04 (1.26)	0.860
Taste maize	4.13 (1.14)	4.22 (1.06)	0.730
General appearance maize	4.17 (1.10)	4.36 (0.88)	0.510
Color clmaize	2.33 (1.42)	2.92 (1.31)	0.02**
Aroma clmaize	2.73 (1.42)	2.98 (1.38)	0.360
Texture clmaize	3.06 (1.43)	3.34 (1.35)	0.330
Taste clmaize	3.23 (1.28)	3.28 (1.43)	0.770
General appearance clmaize	3.21 (1.27)	3.54 (1.27)	0.190
Color clmill	3.02 (1.36)	3.52 (1.28)	0.06*
Aroma clmill	2.87 (1.40)	3.00 (1.23)	0.580
Texture clmill	3.15 (1.56)	3.28 (1.34)	0.730
Taste clmill	3.56 (1.42)	3.64 (1.17)	1.000
General appearance clmill	3.58 (1.23)	3.56 (1.16)	0.900

Supplementary Table 2. Structural Equation Model including control variables.

Parameter	Millet			Maize		
	Coef.	**SE[a]**	**p**	**Coef.**	**SE[a]**	**p**
Female	-0.107	0.092	0.246	-0.125	0.057	0.029**
Age (years)	-0.319	0.126	0.011**	-0.372	0.142	0.009***
Education (years of schooling)	-0.248	0.007	0.000***	-0.150	0.021	0.000***
Information	0.186	0.079	0.019**	0.166	0.118	0.158
Nutrition (factor)	0.283	0.070	0.000***	-0.022	0.114	0.848
Sensory perception (factor)	-0.022	0.096	0.814	0.109	0.118	0.358
N = 102						
Parameter	**Millet porridge combined with CLP**			**Maize porridge combined with CLP**		
	Coef.	SE[a]	p	Coef.	SE[a]	p
wtp_millet	0.578	0.068	0.000***			
wtp_maize				0.397	0.282	0.158
Female	0.009	0.068	0.892	-0.012	0.062	0.851
Age (years)	-0.016	0.041	0.702	-0.082	0.094	0.383
Education (years of schooling)	0.041	0.090	0.646	-0.077	0.078	0.323
Freq. cowpea leaf cons.	0.120	0.022	0.000***	0.026	0.027	0.350
Information	0.099	0.052	0.056*	0.159	0.115	0.168
Nutrition (factor)	-0.103	0.093	0.271	0.104	0.118	0.380
Sensory perception (factor)	0.269	0.057	0.000***	0.239	0.024	0.000***

[a]Standard errors are robust and clustered at market level. *reflects significance at 10%, **reflects significance at 5%, ***reflects significance at 1%.



Supplementary Figure 1. Willingness to pay distribution.

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