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Non-Compliance of Fresh Nile Perch (*Lates niloticus*) Fisheries Products from Uganda

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Authors' contributions

This work was carried out in collaboration among all authors. Author JAS conceptualized the study design and methodology, undertook literature search, data collection, data analysis, writing of the original draft, review & editing of the manuscript, and is the corresponding author. Author IMM contributed to the conceptualization of the study, supervised the work, and provided input through review & editing of the manuscript. Author CKM contributed to the conceptualization of the study, supervised the study, and further provided input through review & editing of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed to assess official monitoring data for fresh Nile perch fisheries products in Uganda. This review focuses on identifying patterns of non-compliance with food safety standards and understanding hazards associated with the Nile perch value chain. The results will serve as a basis for updating/improving pertinent Uganda Standards and regulations. An in-depth analysis was conducted utilizing secondary data for 14 factories encompassing official laboratory results

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spanning twelve years (2010-2022), sourced from the Department of Fisheries Resources records. Frequency distribution tables were employed to determine trends in non-compliance, emphasizing both the frequency and parameters contributing to deviations from safety standards. Examination of non-compliance trends, done using the Mann-Kendall test, revealed a compliance rate of approximately 80% for fresh Nile perch products across the majority (10) of the studied factories. Four factories experienced non-compliance, exceeding 20% of the total monitoring samples at least once during the study period. Among these, only one factory consistently demonstrated non-compliance exceeding 20% throughout the entire review period. There was a correlation between the factories exhibiting the highest non-compliance rates and their history of frequent changes in ownership and/or management over the past two decades. Microbial analysis results highlighted Total Viable Count (TVC), Total Coliforms (TC), and Enterobacteriaceae as the predominant contributors to non-compliance. In addition, heavy metals, particularly lead and cadmium, emerged as prevalent chemical hazards associated with non-compliance in the fresh Nile perch value chain in Uganda. It is recommended that efforts be concentrated on addressing the prevalence of the identified microbiological parameters. Furthermore, a formal review of national standards is advised, with consideration for the removal of parameters such as *Listeria monocytogenes*, *Vibrio cholerae*, and *Clostridium perfringens*, which showed negligible occurrence. Instead, emphasis should be placed on incorporating Enterobacteriaceae, consistently prevalent in fresh Nile perch products across most factories throughout the entire review period.

Keywords: Nile perch; food safety; non-compliance; microbial analysis; hazard assessment.

1. INTRODUCTION

The fisheries sub-sector plays an important role in increasing household incomes and food security worldwide. In Uganda, the fisheries subsector contributes over 5% to the country's gross domestic product (GDP) and is ranked third after gold and coffee [1,2]. Over the late 1990s, Uganda faced significant challenges in the export of fisheries products (chilled and frozen fillets, frozen and chilled headless & gutted fish, chilled and frozen portions) primarily Nile perch (*Lates nilotics*) and Tilapia (*Oreochromis niloticus*). The European Union (EU) imposed bans thrice due to concerns over contamination with *Salmonella* spp, *Vibrio cholerae*, and pesticide residues. Pathogens, if transmitted to consumers through consumption of contaminated fisheries products, may cause a variety of foodborne illnesses. Consequently, stringent regulatory measures, including good manufacturing practices (GMP), hazard analysis and critical control points (HACCP), and adherence to international standards like ISO 9001:2000, were implemented to ensure sustainable production of high-quality fisheries products [3].

The various control measures put in place at the different stages of the fish value chain, subsequently led to improved compliance to standards and other food safety requirements, at least for the export fisheries (chilled and frozen fillets, frozen and chilled headless & gutted fish, chilled and frozen portions) products. However, as reported by Akinwumi and Adegbehingbe [4], the microbial quality and safety of fish are often compromised due to deviations from established guidelines and practices, particularly during transportation, marketing, and storage. Furthermore, inefficiencies in trade facilitation, border controls, and food logistics [5], contributed to non-compliance, resulting in rejections from lucrative markets such as the EU. The economic repercussions of non-compliance, including monetary loss, product destruction, reputational damage, and diminished competitiveness, highlight the urgency of addressing these issues [5].

Strict compliance with global rules has become imperative for countries participating in international trade [6]. However, the impact of these standards on developing countries, particularly with regards to Micro, Small, and Medium Enterprises (MSMEs), has been contentious. Brouder et al. [7] and Bergovoy et al. [8] highlighted the potential negative consequences, noting that stringent standards could exclude MSMEs from international food trade. Local regulations and policies were reported to act as barriers, deterring smaller fish processors from participating in lucrative export markets [9].

Nile perch value chain players in Uganda face challenges in demonstrating compliance with strict food safety standards. The requirement for

regular laboratory testing, as mandated by the Fish (Fishery and Aquaculture Products) (Quality Assurance) Rules, 2017 [10], contributes to increased operational costs and, in some cases, deters processors from engaging in the lucrative export trade. The mandated testing parameters include *Salmonella* spp, *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Clostridium perfringens*, *Vibrio* spp, Total Coliforms, Total Viable Count, arsenic, lead, cadmium, and methyl mercury [11, 12]. However, the scientific justification for including all these parameters, especially in the case of fresh Nile perch products, remains unclear. Notably, the EU, a significant trading partner, requires compliance with only *Salmone*lla spp and *Escherichia coli* [13], while Codex lacks specificity on microbial parameters [14].

This study, therefore, critically reviewed existing data to identify food safety hazards that continually and demonstrably lead to non-compliance in fresh Nile perch fisheries products (chilled and frozen fillets, frozen and chilled headless & gutted fish, chilled and frozen portions) from Uganda. By providing insights into the pertinent food safety parameters, the study aims to guide policymakers in developing strategies to ensure the sustainable public health and trade of fresh Nile perch products (chilled and frozen fillets, frozen and chilled headless & gutted fish, chilled and frozen portions) from Uganda.

2. MATERIALS AND METHODS

Secondary data were obtained from review of the official monitoring laboratory results of fresh Nile perch fisheries products (chilled and frozen fillets, frozen and chilled headless & gutted fish, chilled and frozen portions). The data were obtained from records of the Department of Fisheries Resources (DFR), the Central Competent Authority for fish and fisheries products in Uganda. Microbial laboratory test results were reviewed for the presence of *Salmonella* spp., *Vibrio cholerae*, *Escherichia coli, Clostridium perfringens, Lysteria monocytogenes* and *Staphylococcus aureus.* Chemistry laboratory test results focused on pesticides residues and heavy metals. The review was aimed at identifying the non-compliant samples, highlighting the parameters leading to non-compliance, and aggregating data to pinpoint the hazards that mostly contributed to non-compliance.

The data obtained spanned twelve years (2010-2022) and was for fourteen (14) fish factories engaged in fish processing and export. To ensure confidentiality, the factories were assigned random codes (AA through to NN). Despite existing for over twenty years, most of the factories covered in this study experienced changes in management and/or ownership over the years. Some factories lacked test results for some years due to dormancy caused by changes in ownership or suspension from processing for export. The DFR explained that local market processors, dealing with smaller quantities, faced less rigorous monitoring compared to those exporting.

2.1 Data Analysis

Data analyses were conducted using STATA version 15 SE [15]. Frequency distribution tables were generated to assess non-compliance frequencies and proportions across fresh Nile perch fisheries products and companies over the twelve-year period. Trends in non-compliance were identified, and a Mann-Kendall test was conducted to statistically evaluate monotonic upward or downward trends over the entire 12-year period [16]. The Mann-Kendall test, chosen because of its independence from data distribution assumptions, and its insensitivity to time series length, aligns with the 12-year dataset [17].

3. RESULTS AND DISCUSSION

3.1 Proportion of Non-compliance of Fresh Nile Perch Fisheries Products

Fig. 1 shows the proportion of non-compliance of fresh Nile perch fisheries products in different fish processing companies in Uganda during the period of 2010-2022. The compliance rate was about 80% for the fresh Nile perch fisheries products from most of the factories. Only four factories had experienced non-compliance of their fresh Nile perch fisheries products being over 20% at least once over the study period, with products from only one factory (AA) showing consistent non-compliances of more than 20% for the entire review period. The non-compliance level was much lower than that fish from Morocco was found non-compliant in a period of five years (2011 – 2015) [5].

Since this study reviewed compliance of the official monitoring samples taken by the Competent Authority in Uganda, it is possible

that appropriate corrective actions were implemented prior to exporting the products. This could be one of the reasons why Uganda's fishery products have not been identified among those regularly rejected in the EU and other stringent markets. According to Amico et al. [18], 60% of the products that were rejected in the EU market due to non-compliance, were mainly aquatic products with Italy accounting for 35.7%, followed by Vietnam and Morocco. About 39.3% of those non-compliances were classified as serious, owing to a high prevalence of heavy metals, pathogenic micro-organisms, poor temperature control and unsuitable transport conditions [18] yet according to FAO [19], these countries with the highest rejections are among the giants in the EU fish market.

This study further observed that factories with the highest level of non-compliance over the study period had experienced the highest number (over five times in the last 20 years) of change of ownership and/or management. Factory BB had the most compliant fresh Nile perch fisheries products for two years (2010 and 2016) when it had non-compliance levels of 0%, while factory AA consistently had the most non-compliant fresh Nile perch fisheries products over the entire study period, even peaking at almost 80% non-complying samples in 2019. On average, the majority of the fish factories in Uganda had fresh Nile perch fisheries products with non-compliance levels of below 10% (Fig. 1) which is consistent with the findings of Kareem et al. [5], in which Uganda is not among the countries with high rejections from the EU market. According to Kareem et al. [5], 22.43% of the fish products from Morocco were rejected by the EU market between 2008 and 2013, due to non-compliance to the safety standards. Morocco, Senegal, Tunisia, Ghana and Kenya respectively had 154, 57, 38, 17 and 4 consignments of their fish products rejected between 2008 and 2013 from the EU market owing to failure to comply with the EU food safety standards [5].

Fig. 2 shows that overall, non-complying samples depicted an increasing trend before 2018 and a declining trend from 2018 to 2022. A Kendal test of monotonic trend reported an increasing trend (test statistic=0.0769) with a P-value of P=.71, implying that the trend was not statistically significant.

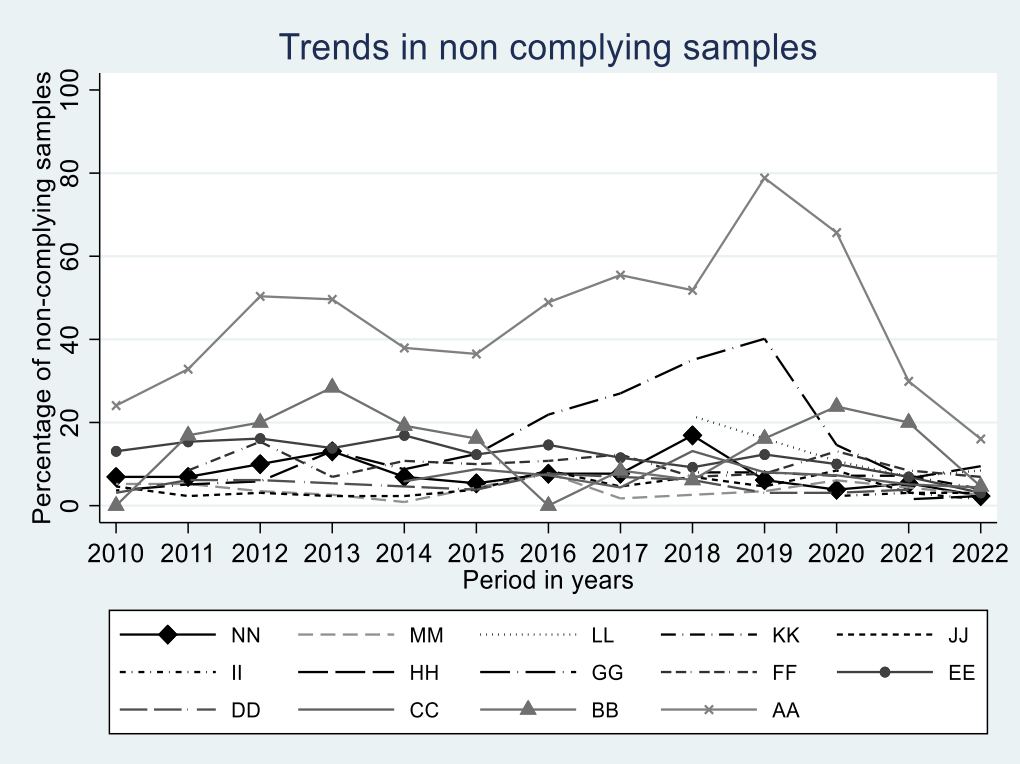

Fig. 1. The proportion of non-compliance of fresh Nile perch fisheries products in different fish processing companies in Uganda during the period of 2010-2022. AA to NN are codes randomly assigned to the different fish processing companies to ensure confidentiality

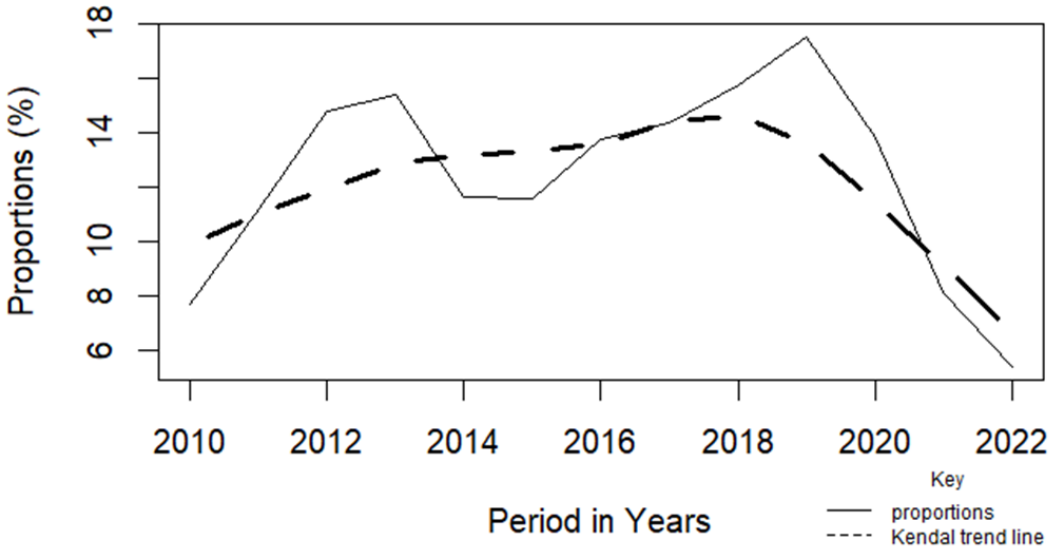

Fig. 2. Overall Proportion of non-complying samples in different companies between 2010 and 2022 with a trend line

3.2 Reasons for Non-compliance in Fresh Nile Perch Fisheries Products

Whereas The Fish (Fishery and Aquaculture Products) (Quality Assurance) Rules, 2017 Clause 11 (d) require that "fish must have undergone health and sanitary checks in accordance with the relevant national standards" [10], the Ninth Schedule of the same rules, provides the standards by which objective assessment of compliance is to be determined [10]. It was observed that there is a variation in the parameters stipulated in the Ninth Schedule, from the ones stipulated in the relevant national standards [11,12], and the actual parameters being tested for in the laboratories. The results in this report were based on the actual parameters that were being tested for in the laboratories, as seen from the reviewed official laboratory test reports archived at the Department of Fisheries Resources.

Figs. 3a and 3b show that across all the factories, for most of the years, Total Viable Count, Total Coliforms, Enterobacteriaceae, and *Escherichia coli* were the prevalent microbiological test parameters causing non-compliance while the chemical parameters for non-compliance were mainly heavy metals, particularly lead for most cases and cadmium in one instance. Pesticide residues contributed to non-compliance in products from only two factories (DD and EE), and the non-compliance was detected in two different years 2016 and 2017, respectively. These study findings correspond to the findings of the EU study that found the majority of the fish consignments that were being rejected were due to presence of mycotoxins (22.43%), poor control systems (20.32%), pesticide residues (15.57%) and pathogenic micro-organisms (5.89%) [5].

The observed variation in the level and type of microbial contaminants (Total Viable Count, Total Coliforms, Enterobacteriaceae, and *Escherichia coli*) in the fish samples could be due to the fact that the results were for samples from different factories. As reported by Gildas et al. [20], the postharvest handling, sanitation and hygiene, the quality of the fish samples at the point of landing as well as storage conditions could be different across all the factories and would definitely have an effect on the microbial quality of the fish products at all the various factories. The secondary data used in this study could not be stratified according to sampling stage, storage conditions of the fisheries products prior to sampling nor methods of microbial analysis used. Therefore, it would be prudent to undertake a study to 1) assess the microbial quality of fish products from the fish handling facilities within the fresh Nile perch value chain, 2) determine the most prevalent microorganisms and their possible sources, and 3) establish whether these microorganisms differ across the different facilities.

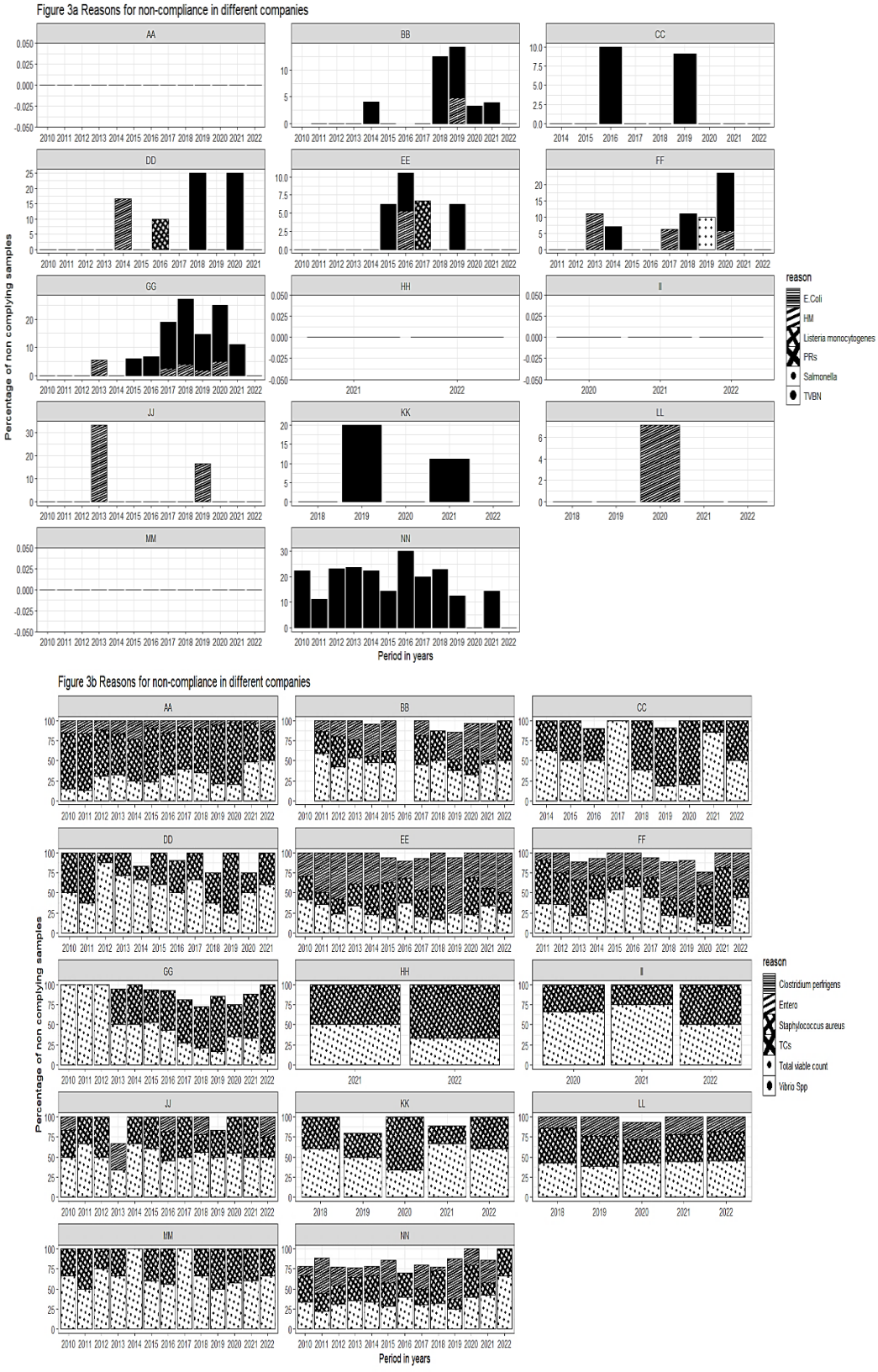

Fig. 3a & 3b. Test parameters that contributed to the non-compliance of fish samples per company between 2010 and 2022. AA to NN are codes randomly assigned to the different fish processing companies to ensure confidentiality

Further still, the reasons for non-compliance within the Ugandan fresh Nile perch value chain did not differ much from other fish exporting countries. According to Renjini et al. [21], 40% of the consignments of fish exports from India to the EU market were rejected between 2005 and 2019. The fish from India was rejected due to various reasons including: 20% due to poor temperature control, 11% due to cadmium contamination, and 7% due to *Salmonella* spp contamination [21]. Likewise, cadmium and *Salmonella* spp contamination are some of the causes for non-compliance observed in the current study findings.

It is worth noting though, that the EU food safety standards have been reported to act as a barrier to Africa's fish exporters. The EU has been reported to use food safety standards to protect their market as well as some of their fish species that have not yet attained a good market share by limiting the entry to the EU market of the "cheap and tasty" fish species from these African countries [22,23].

Total Volatile Bases- Nitrogen (TVB-N), while not considered as a food safety hazard *per se*, but rather a quality parameter indicating freshness of the fishery products, contributed to non-compliance in samples from one factory (FF) only once in 2019.

Data aggregated for all companies indicates that Total Coliforms and Total Viable Count were the most prevalent reasons for non-compliance over the entire period, with increasing trends over time (Fig. 4). However, as indicated in Table 1, the trend for both parameters (Total Coliforms with P-value of P=.626 and Total Viable Count with P-value of P=.542) was not statistically significant. This would imply that the control measures put in place as a result of the ban, have actually been effective.

The increasing trend in non-compliance observed in the current study did not differ much from the trend observed by United Nations Industrial Development Organization (UNIDO) on the EU and US market in the period between 2002 to 2008 where there was an overlapping increase and decrease in the total number of consignments rejected by both markets [24]. Within the six year period of that study (2002 to 2008), 2,680 consignments of fish and fishery products from third countries were rejected on the EU market second to nuts and seeds (4,680) owing to non-compliance and a similar trend was observed on the US market [24]. The reasons for the non-compliance were stated as: 27.7%, 20.3% and 20.1% in terms of veterinary drug residues, microbiological contaminants and heavy metals, respectively [24].

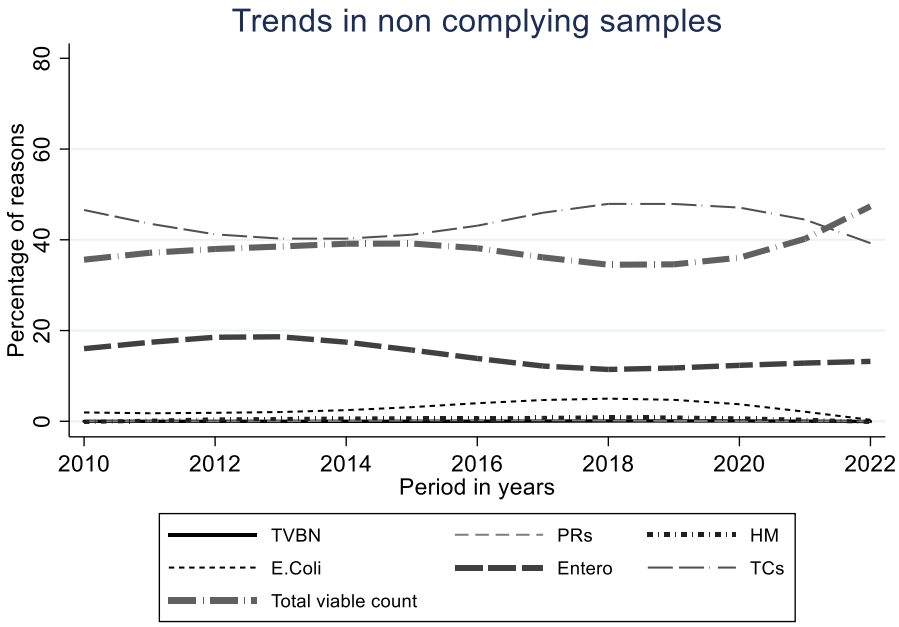

Fig. 4. Test parameters that contributed to the non-compliance of fish samples aggregated for all companies between 2010 and 2022

Table 1. Overall Kendal tests of trends for the different test parameters aggregated for all companies between 2010 and 2022

Reason	Kendal statistic	Kendal P-value
Total Volatile Bases-Nitrogen	0.196	0.423
Pesticides Residues	0.024	0.922
Heavy Metals	0.214	0.333
E. coli	0.282	0.179
Enterobacteriaceae	-0.410	0.051
Total Coliforms	0.103	0.626
Total viable Count	0.128	0.542

Enterobacteriaceae which is neither a required parameter in the relevant Uganda National Standards [11, 12] nor in the Ninth Schedule of the Fish (Fishery and Aquaculture Products) (Quality Assurance) Rules 2017 [10], was being tested for and it was the third most prevalent reason for non-compliance over the entire period. As shown in Fig. 4, it depicted a decreasing trend over the period, which trend according to the Kendal test results shown in Table 1 was not statistically significant (P =.05) over the entire period.

The microbiological contaminants observed in the current study correspond to those that were reported in a study done in the US where 937 foodborne outbreaks were attributed to consumption of fish contaminated with more or less similar microorganisms in the period between 1998 to 2018 and this resulted into 5,011 illnesses, 364 hospitalization and 4 deaths [25]. According to Sheng & Wang [25], *Salmonella* spp*, Clostridium botulinum* and *Shigella* ssp were responsible for 15, 14 and 3 outbreaks, respectively during the period of that review. When ingested, microorganisms in fish pose serious health issues to the consumers leading to symptoms such as severe diarrhoea, fever and abdominal cramps among others [26]. Therefore, control measures need to be put in place to minimize microbial contamination in order to ensure that fresh Nile perch fisheries products are safe for human consumption.

The micro-organisms responsible for non-compliance in the current study were also found in a similar study done in Benin which assessed the microbial profile of smoked fish and smoke-dried fish where 66.7% and 22.2% of smoked fish and smoke-dried fish were rendered non-compliant with the set limits according to the EU standards [20]. According to Gildas et al. [20], the fish samples in the Benin study, had a high prevalence of Enterobacteriaceae (63.9%), *Escherichia coli* (27.8%) but were free of *Salmonella*, *Listeria monocytogenes* and *Staphylococcus aureus.*

4. CONCLUSIONS

The overall compliance of fresh Nile perch fisheries products from all factories over the last twelve years has been substantially above average at approximately 80%. The 20% non-compliance is largely contributed to by three microbiological parameters (Enterobacteriaceae, Total Coliforms and Total Viable Count) out of the eight stipulated in the relevant national standards. On top of focusing efforts on mitigating the prevalence of the three microbiology parameters, the Department of Fisheries Resources should consider requesting a formal review of the relevant national standards. The revision of the standards would need to consider the removal of those parameters that are not necessarily of significant occurrence like *Listeria monocytogenes, Vibrio cholerae*, and *Clostridium perfringens*, and instead introduce *Enterobacteriaceae* that has been consistently prevalent in fresh Nile perch fisheries products from most of the factories for the entire period under review. It is important to undertake an independent study to assess the microbial quality of fisheries products within the fresh Nile perch value chain in Uganda to confirm the prevalence and diversity of pathogens, and to further support the request for review of the relevant national standards.

DATA AVAILABILITY

The datasets generated during and/or analysed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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