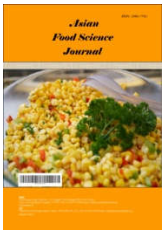

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# Vendor Characteristics, Practices, Microbial Contamination of Fish and Oil Quality in the Street Vending of Deep-fried Fish in Peri-urban Nairobi, Kenya: Case of Kasarani Sub-county

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author MNS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JKI and LGN managed the study development and edited the manuscript. Author MNS managed the final manuscript. All authors read and approved the final manuscript.*

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## ABSTRACT

**Aim:** The main objective of the study is to assess the vendor and environmental hygiene, microbial contamination of deep-fried tilapia sold, and the quality of the oil used in the streets of Kasarani sub-county
**Study Design:** Cross-sectional study.
**Place and Duration of Study:** Kasarani Sub-county and The University of Nairobi Department of Food Science, Nutrition, and Technology laboratory between January 2019 to July 2020.
**Methodology:** Structured questionnaires, checklists, analytical observations, and market observations were used to collect data from the street vendors. After the collection of the fish samples, microbial analysis of the fish samples was carried out using standard methods for Total coliforms and *Staphylococcus aureus.* The deep-frying oil was sampled for analysis of color and viscosity. Results were evaluated using national standards.

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**Results:** The findings indicated that all the vendors have received a basic education and that all vendors fall under the low-income group. The most contaminated part of the fish by *Staphylococcus aureus* and total coliforms is the gills. The highest contamination was from Clay city ward (2.46 ± 0.43) while the least contaminated was from the Mwiki ward (1.28 ± 1.17). The total coliforms and *Staphylococcus aureus* concentration are significantly different between wards p (<0.05) as the p-value was 0.003 and 0.043 respectively.
**Conclusion:** The findings indicate that the vending practices carried out are unsanitary. The fish as sold were contaminated with total coliforms and *Staphylococcus aureus* at high levels indicating poor hygiene procedures. The environment is characterized by poor sanitation and hygiene. The oil used for deep frying was characterized by dark color and high viscosity indicating prolonged usage of the same oil. Policies governing street vending and the environment should be reinforced to prevent the occurrence of hazards resulting from street vended fish.

*Keywords: Street vending; fried fish; microbial contamination; safety; hygiene; peri-urban; Nairobi; Kenya.*

## 1. INTRODUCTION

Street foods refer to those foods that are sold on the street sides. They could be raw, prepared, or even processed, in most cases ready to eat. There are three groups of ready to eat street vended foods; foods prepared in small factories and sold by mobile vendors; foods prepared at the homes of street vendors and sold; foods prepared and sold on-site in the street [1,2] A study done by Deore and Lathia [3] in Ahmedabad, India showed that street vendors account for a considerable share of urban employment and revenue generation. Riveraa and Semradb [4] observed that street foods provide food at the comfort and convenience of the general public by making food available for everyday use at a lower price than informal restaurants. The foods also play cultural and heritage roles in many of our societies. They have also been found to make cities more vibrant by adding color and offering diverse experiences [5,6]. Consumers are also drawn to gustatory attributes such as unique flavors [7,8]. Deep-fried vending is a common practice in Kenya, mainly in the informal settlements in the peri-urban areas. In Kenya, these settlements are the main abodes of the low-income population. The fish is usually sold as fried. Frying is done in a pan of different sizes, often of metal, and usually locally fabricated. The frying utilizes vegetable oil. The oil is usually not changed at any point during a frying day, only topped when levels go down. Sometimes the oil from the frying fish tops up the frying oil. Vending of deep-fried fish is usually by persons with very little education and therefore poor hygiene knowledge. The business is usually practiced in sites with very little infrastructure as roads and water and poor sanitation. The product is therefore amenable to contamination from debris and microorganisms, emanating from the dusty streets, limited wash water, and even the handling utensils.

A study carried out in Gikomba and Githurai markets in Nairobi county on food handling practices and environmental factors associated with food contamination [2], determined that vending sites usually do not have adequate basic facilities including toilets and handwashing facilities. This is mostly because these vendors are usually focusing on nearness to customers. This ultimately results in the enhancement of the incidence of foodborne illnesses and disease transmission (Mjoka and Selepe, 2018) [9].

Even after the introduction of modern toilets, there is a challenge of inadequate sewerage systems which may include burst sewers. This provides an environment conducive for flies and other vectors for pathogen transmission [10,11]. Lack of waste disposal services, proper drainage for the liquids, and wastewater would lead to the buildup of the garbage which would provide breeding grounds for the insects and other pests which would lead to infections [12].

Frying kills the inherent microorganisms in the fish. Any contamination with microorganisms on the fried fish is therefore subsumed to be from post-frying handling by the vendors and the vending environment. If the fried fish is to be stored for a time, the presence of moisture in the fish may permit the growth of bacteria and mold in fish flesh. The microbial growth may lead to discoloration and development of off-odor. These products when consumed may cause health problems to the consumers. The most important microorganisms involved in this hazard include *Staphylococcus aureus, Escherichia coli,*

*Bacillus cereus* and Aeromonas species [13]. Tahsin et al., 2017 state that the deterioration of fish occurs due to; bacterial invasion and putrefaction. Enzymatic autolysis, chemical oxidation or mechanical damage, and environmental optimization facilitates the growth of microbes (Ravishankar, 2016; Mathendu, 2017).

Frying oil changes with use from fresh oil through its optimal state to a degraded condition. Rashed et al., 2019. The degradation of oil reactions includes thermal, oxidative, and hydrolytic reactions. They include hydrolysis [14]. Oxidation of the lipids is a complex process and involves free radical chain reactions and polymerization [15,16].

This study was designed to evaluate the hygiene practice of the vendors and the vending environment of the deep-fried tilapia fish, and the possible contamination of the fried fish with microorganisms as eaten.

## 2. MATERIALS AND METHODS

### 2.1 Study Site

This study was carried out in Nairobi County no.47 in Kenya. The study focused on Kasarani sub-county shown in Fig. 1 which is 152.60 $km^2$, it contains the following wards: Clay City, Mwiki, Kasarani, Njiru, and Ruai. Kasarani Sub-County was purposely selected due to the availability of the deep-fried tilapia fish vendors. The setup for the frying of the fish in Kasarani Sub-County is the same as the vending of the fish as most fryers are also the vendors of the fish.

### 2.2 Methods

#### 2.2.1 Structured questionnaire

A previously pre-tested structured questionnaire was used to collect information on the socio-demographic and socio-economic characteristics of the tilapia vendors including gender and their vending practices of the fryers from frying to product disposal.

#### 2.2.2 Checklist of questions

The checklist of questions combined with visual observation was used to evaluate the sanitation of the vending environment the utensils used and the environment under which the food vendors operate, and how the fish was processed.

#### 2.2.3 Microbial analysis of the deep-fried tilapia fish at vending

Simple random sampling was then used to select 16 vendors from whom the samples of fish and oil were sampled. Each vendor selected provided a sample of fish and 200mL cooking oil. The samples of fish were collected aseptically from the street vendors using sterilized containers, stored in the refrigerator overnight. They were then transported in a cool box at 4ºC with ice cubes to the University of Nairobi Department of Food Science, Nutrition, and Technology laboratory. On arrival, analysis began immediately with the separation of the different parts: head, gills, muscle, and fins. After separation, the samples were placed in the peptone water and dilutions were made. The various microorganisms were then enumerated.

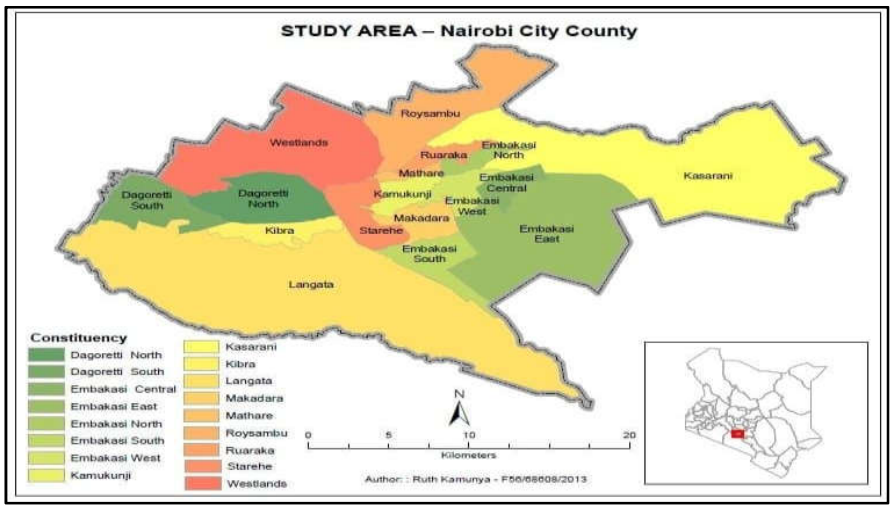


**Fig. 1. Map showing Nairobi county in Kenya**

*2.2.3.1 Enumeration of total coliforms*

Total Coliforms: The Violet Red Bile Agar was prepared by weighing the required amount and diluting it with 1000 mL of water. This was then boiled to dissolve. The agar was then placed in an autoclave for fifteen minutes to sterilize it. It was then kept in the oven at 55ºC.

1 mL of the fish sample was inoculated on sterile plates and around 18mL of Violet Red Bile Agar aseptically poured and each plate swirled to mix the inoculums evenly. The plate was then incubated at 35-37ºC for 48h.

*2.2.3.2 Enumeration of Staphylococcus aureus*

*Staphylococcus aureus* detection: Manitol Salt agar was prepared by weighing the required amount and diluting it to 1000 mL. It was then boiled to dissolve. It was then placed in the autoclave to sterilize it. It was then kept in the oven at 55$^{o}$C. 1 mL of the sample was inoculated on sterile plates and around 18 mL of Manitol agar aseptically poured and each plate swirled to mix the inoculums evenly. The plates were then incubated at 35-37ºC for 48h.

### 2.2.4 Determination of the color and viscosity of the frying oils

The oil was purchased from the street vendors and within 24 h examined for physical parameters: color and viscosity.

*2.2.4.1 Color*

The color was determined by the use of a precision Colorimeter of the PCE-CSM series from PCE instruments. Its specifications are outlined in Table 1.

*2.2.4.2 Viscosity*

The viscosity was determined by the use of a flow cup viscometer whose specifications are outlined in Table 2. It involved covering the hole at the bottom of the orifice. The oil samples were distributed according to the wards they were collected from. The cup was then filled with the oil according to each ward. Excess oil was scraped from the cup. The hole was then uncovered from the bottom. A stopwatch was then activated while simultaneously opening the hole at the bottom of the cup. As soon as the flow stopped, the stopwatch was stopped and the time it took was recorded. The value recorded in seconds was then converted to Centistokes according to the ISO standard calculator.

## 2.3 Data Quality Control

The questionnaires were pretested using at least 5 people. Based on the comments from pretesting adjustments were made. The questionnaire was organized into the following three main sections: Socio-economic and socio-demographic characteristics, the vending practices, and the vending environment.

Data from the laboratory investigation and media preparation was obtained from preparing and using standard operating procedures and therefore ensuring the quality of data is kept. The analysis was also done in duplicate.

**Table 1. Technical specifications of the PCE colorimeter used**

| Technical specifications | |
|---|---|
| **Sensor** | **Silicon photoelectric diode** |
| Color space | CIEL *a*b*C*h<br>CIEL*a*b<br>CIEXYZ |
| Color difference formula | E*ab<br>L*ab<br>E*C*H |
| Light source | 365 |
| Light source device | LED Blue light |
| Repeatability | Standard Deviation within E*ab 0.008<br>Measurement conditions: an average of 30 measure of standard white plate |

**Table 2. Technical specifications of the PCE Cup viscometer used**

| Technical specifications | |
|---|---|
| Model | PCE 128/4 |
| Viscosity range (cSt) | 34-155 |
| Materials | Cup: Anodized aluminum<br>Orifice: Stainless steel |
| Standards | BS EN ISO 2431/ ASTM D5125 |
| Dimension | Height: 85mm<br>Interior: 50mm<br>Exterior: 85mm |
| Weight | Approx. 310g |

## 2.4 Statistical Analysis of Data

All measurements were carried out in duplicate. Significance was defined by $p< 0.05$. The microbial counts will be normalized by transformation to log 10 CFU/mL to establish the statistical significance of microbial loads in different samples. SPSS v. 23 and Microsoft Excel 2010 were used for data processing and analysis. Frequency of distribution for categorical data to explore the explanatory variable associated with outcomes.

## 3. RESULTS AND DISCUSSION

### 3.1 Socio-demographic and Socio-economic Characteristics of the Vendors

#### 3.1.1 The socio-demographic characteristics

According to the study, the majority of the street vendors were female as shown in Table 3. This may be due to the traditional Kenyan culture that food is only to be handled by women.

The fish fryers were between 24 and 60 years. The majority of the vendors were between 24 and 35 years as shown in Table 3. This is as a result of most of the vendors not being qualified enough to be employed elsewhere. Also, lack of employment opportunities in the country has led most youth to venture towards starting small businesses such as street vending of fish to survive the harsh economic times. This is similar to what was discovered by Ahmed et al*.,* 2019, where the vendors lied between two-thirds in the 26-35 and 36-45 age brackets.

Seventy-four point two% of the street vendors are married while 25.8% are single. This may be due to the need to provide for the family unlike for single people who may not have many responsibilities. This is different from what was observed by Rahman et al. [17] that single street vendors are more (52.4%) than the married (47.6%) as married people will tend to look for jobs that provide more to support their families.

From the study, most of the street vendors had received basic education that is primary school as shown in Table 3, and were, therefore, all literate, able to understand the questions asked. None of them, however, has received tertiary education. According to Chakraborty and Koley, 2018 [18] people settle on street vending because it necessitates less education, unskilled knowledge, and comparatively minor resources compared to other occupations.

#### 3.1.2 The socio-economic characteristics

The majority of street vendors get their livelihood through vending of fish. 90.3% of the street vendors are self-employed while 9.7% of the vendors are employed by others. Forty-one-point-nine (41.9%) of the street vendors earn Kshs. 60,000 -100,000 annually. 3.2% of the street vendors earn less than 10k annually. Those earning above Kshs. 100,000 annually are 16.1%.

According to the Economic Survey by the Kenya National Bureau of Statistics (2017), a lower income earner in Kenya earns between Kshs. 23670 and below. A middle-income earner earns between Kshs. 23,6721 and Kshs. 119,999 while the higher income group consists of those who earn above Kshs.120,000 monthly.

From the study, therefore, all the street vendors lie in the lower income group as they all earn below Kshs 23,670 monthly.

**Table 3. Socio-demographic characteristic of the vendors**

| Characteristic | Characteristics | Number | Percent |
|---|---|---|---|
| Gender | Male | 8 | 26.o |
| | Female | 23 | 74 |
| Age | 24-35 | 19 | 61.3 |
| | 35-50 | 11 | 35.5 |
| | 50 and above | 1 | 3.2 |
| Marital status | Single | 8 | 25.8 |
| | Married | 23 | 74.2 |
| Level of Education | Did not complete primary education | 3 | 9.7 |
| | Completed primary education but did not proceed to secondary education | 10 | 32.3 |
| | Completed primary education and proceeded to secondary education but did not complete it. | 8 | 25.8 |
| | Completed primary education, proceeded to secondary education, and completed it. | 10 | 32.3 |

The income generated, however, depends on the number of hours one spends selling and the number of fish sold. This also depends on the number of days one sells because they employ themselves. The income of the respondents exposes important facts about the standards of living of these street vendors. Those earning the lowest income will barely sustain the livelihood of a small family.

## 3.2 Vending Practices of the Fryers from Frying to Product Disposal

### 3.2.1 The source of the fish

The source of the fish sold in Kasarani sub-county is primarily from the Gikomba market. A study done by Mwangi et al. [19] observed that there were low levels of use of ice by fish handlers at the Gikomba market. This may compromise the quality of fish. The researcher also observed the reuse of packaging materials and baskets in the Gikomba market. There was also a great need to educate the fish handlers on good hygienic practices and taking care of the environment which would eventually lead to the selling of good quality fish. However, when the fish is introduced to the hot frying oil it is considered sterile and therefore present contamination will result from the subsequent processes and not necessarily from the source of the fish.

During the transportation of the fish to the frying site, seventy-seven point four% (77.4%) of the street vendors use public transport to get their fish to the frying point. This involves putting the fish in buckets and boarding a public service vehicle to the frying site as they are not able to afford private means to the frying sites. The fish are put in clear bags and then put in buckets for ease of transportation. Those who transport their fish like this are those that get their fish from the Gikomba market in Nairobi. They do not use ice to transport the fish. This is also seen in Cortese et al. [20]. In Ruai ward and Njiru wards, the fish are transported to the vending environment using a truck or using a cool box carried by motorbike operators.

### 3.2.2 Frying of the fish

One hundred percent (100%) of the street vendors prepare the fish using the following steps: Washing of the fish, some fish are bought while they have already had the guts removed but others are not and so some of the vendors degut the fish as they wash. After washing and degutting, the fish are cut slightly on the muscles three times to allow them to fry effectively. This was also observed by Sainani and Kapute [21] and Jayasena et al. [22]. The vendors then prepare the frying place by adding oil to metallic deep pans that can withstand high levels of heat.

The oil is allowed to heat for about 10 minutes after placing it in the pan. When the heat is ready, fish are placed in the oil gently and are fried for 5, 10, 15, 20 or 30 minutes which constitute 12.9%, 22.6%, 35.5%, 22.6% and 6.5% of the street vendors respectively while being turned to the other side to cook on both sides. Once the first batch is removed other fish are added to the oil [23].

All vendors stated that they used oils. 22.6% of the vendors used oil that is repackaged by retailers and bought according to customers'

specifications. 19.4% use Salit oil, 16.1% use Rina oil, 12.9% use Top fry, 9.7% use Halisi, Ufuta (6.5%), golden fry(6.5%). A study carried out by Toklu in 2017 [24], shows that branded oils have good physical and chemical quality with minimal microbial contamination compared to unbranded vegetable oils.

The most evident change in oil that was being used is the color (darkening). Many of the compounds in the food or their breakdown products react with the oil which leads to color formation. The quantity of oil absorbed and that which needs replacing is a good indicator of the stress that the oil undergoes during daily operation [25]. 54.8% of the vendors re-use the oil that remained from the previous day and mixed it with fresh oil till it reaches an amount that will be sufficient for the number of fish one has. 32.3% of the vendors replenish the oil they use whenever it ends, it does not matter the time of day. 12.9% of the vendors stated that they replenish the oil they use in frying after a day's use. They do not recycle the oil but discard whatever was left for the day and get a new batch.

### 3.2.3 The serving containers

Forty-five point two% (45.2%) of the street vendors have plastic sieving bowls to allow the oil to drain from the fish once it is removed from the fire. The plastic bowl is then placed on top of a sufuria or on top of a tray to drain the oil which is recycled back to the pan once it collects enough oil. 19.4% use metal trays to drain oil from the fish, 9.7% use plastic trays to drain the oil while 25.8% of the vendors usually place the fish directly on the display table covered with Khaki paper or recycled boxes as shown in Fig. 2 without letting it drain oil elsewhere [26]. This is unhygienic as the boxes or khaki paper are usually placed carelessly on the ground which makes them prone to contamination.

### 3.2.4 Product disposal

One hundred% (100%) of vendors use khaki paper to package their fish while vending. These papers are usually recycled from the packaging used for bales of flour. This packaging is the one that is divided into different portions to serve different customers. There are several risk factors associated with it including the fact that it is usually placed on the ground and dusted whenever one wants to serve a customer.

The heaps of khaki paper serve as good breeding sites for pests like cockroaches and flies. In the process of packaging, the vendors blow air from the package thus allowing transmission of pathogens (Cross-contamination) [27] (Janeja, 2016).

The cost of the fish varies according to the size of the fish. The smallest fish cost 50 Kenyan shillings, this was sold by 3.2% of the vendors. 25.8% of the vendors sold fish that are slightly bigger at 60 and 80 shillings. The next size of fish is sold by the vendors (29%) at between 100 and 200 shillings. The majority of the vendors 41.9% sell their fish at prices beginning from 200 to 600 shillings.

Forty-one point nine% (41.9%) of the street vendors stated that they fried all the fish that they have in stock for the day and for them to stay safe, they leave them in the open air, display cabinets or cupboards till the next day when they would be able to sell them. 35.5% of the vendors have freezers where leftover fish are returned in the freezer to be sold the next day as the first batch. 16.1% fry all the fish but those that are leftovers are sold to a nearby hotel to be served to customers at the hotel. 6.5% said they do not get leftover fish but they ensure that all the fish available are sold on that same day.

Foods containing oil experience rancidity during the storage process. This speed of rancidity depends on the storage method used. The fried fish stored in the open air is prone to getting spoilt faster as the process of rancidity is not being controlled. Those that have freezers to store fresh fish reduce the multiplication of bacteria in the fish, hence preventing the spoilage of the fish preserving its quality. This is an agreement with a study carried out by Maulana et al. [28].

Fifty-one point six (51.6%) of the vendors sell the fish whole while 48.4% sell the fish both whole and in pieces depending on the preference of the customer. This also depends on the amount the customer is willing to spend. They are cut into pieces for those who cannot afford to buy a whole piece of fish.

Eighty-three point nine (83.9%) of the street vendors allow both eating at the site and the carrying away of the fish. This is affected by the availability of space. A vendor in Ruai ward had included a hotel in his vending facility where the fish would be accompanied with ugali and traditional vegetables. 16.1% of the street

vendors only allow the carrying away of the fish bought.

#### 3.2.5 Serving of the customers

It was observed that 45.2% of the vendors use a piece of khaki paper to serve customers themselves. 25.8% of the vendors use bare hands as shown in Fig. 2 to serve customers, which is a source of contamination considering that the same hands are Used to handle money, the raw fish or even to make phone calls. 22.6% of the vendors allow the customers to choose the fish themselves. They hand a piece of khaki paper to help them choose what they want. After choosing, it is wrapped in khaki paper and sold. 6.5% use a big spoon to place the fish on khaki paper it is then wrapped and sold [29].

#### 3.2.6 Complaints from the purchasers of the fried fish

Nineteen point four (19.4%) of the customers claimed they have never received complaints. 80.6% admitted that they have received complaints especially stomach upsets.

### 3.3 Hygiene and Sanitation of the Vending Environment and Microbial Contamination of the Tilapia at Vending

#### 3.3.1 The hygiene and sanitation of the vending environment

*3.3.1.1 The vending environment*

There are reports of uncontrolled access to informal sector activities in virtually every segment of urban space [30]. Due to their quest to earn more, street vendors locate themselves at strategic points with heavy human traffic where they can be seen easily. The encroachment of street vendors' structures on walkways reduces road capacity. Street vendors lack basic facilities and therefore operate under a non-conducive environment which enables unhygienic practices. 100% of the surroundings of the vending environment were not free of potential contaminants. The vending places were located at the roadside and were therefore exposed to dust from roads, exhaust fumes from vehicles. These are a source of contamination of the fish [31].

*3.3.1.2 The site and facilities*

As observed by Ogunkan [30], street vendors use kiosks, under umbrellas, use of display tables, metallic containers, or makeshift structures. The use of metal containers has negative implications for the vendors and also the environment. This is due to its non-biodegradability. Its high heat storage capacity and high thermal conductivity impairs users' comfort and builds general environmental discomfort. The implication of having temporary structures that characterize street vending is that their escalation along the major roads distort the landscapes and deface urban sight and constitute environmental eyesores.

Thirty-eight point seven (38.7%) of the vendors carry out their vending in the open with tables only and with umbrellas. 22.6% of the vendors use sacks to create temporary stalls to enable them to prepare and sell their fish.35.5% of the vendors use metal sheets (mabati) to make stalls. 3.2% store their resources in containers but they fry the fish just in front of the container. The vending places were poorly constructed which exposes the food to several contaminants.

**Fig. 2. The use of recycled fiberboard sheet to display the fish for sale and serving to customers using bare hands**

*3.3.1.3 The vendors*

One hundred% (100%) of the street vendors did not have handlers' medical certificates. This is a great risk to human health as the issuing of medical certificates ensures that those who handle food are fit to do it.

Observations during the study showed that 77.4% of the street vendors wore protective clothing that is aprons and head coverings. 64.5% of them were clean while 12.9% were unclean, 9.7% of them did not have any protective clothing worn. This is similar to what is observed by Eliku, 2016. Protective clothing helps prevent cross-contamination from different areas that may be carrying potential contaminants including hair, clothes and hands. [32].

None of the street vendors had training in food safety and hygiene and were therefore carrying out their practices after teaching themselves (trial and error basis). Food handlers need to be trained on food safety and hygiene to assure the safety and quality of the fried fish. Lack of training leads to the vendors carrying out unhygienic practices in unsanitary conditions. They need to be trained on handwashing general cleaning and good sanitation procedures, they also need the training to ensure that whatever they are taught is implemented by the vendors in their vending sites [33,34].

*3.3.1.4 Water availability*

Water is an important raw material in street vending operations. One major problem faced by street vendors is the supply of water of acceptable qualities and sufficient quantities for drinking, cleaning and other operations (Nemo et al., 2017). This problem is observed in Kasarani sub-county where potable water is unavailable at the vending sites and therefore the vendors have to walk long distances carrying water. 77.4% of the vendors get the water from the Nairobi city council while 22.6% buy from water vendors whose source of water is unknown. It is a costly raw material and is therefore re-used many times. This is a source of contamination as the water used to wash the fish is the same water used to wash the utensils to be used which leads to the occurrence of cross-contamination. Fig. 3 shows the condition of the water.

Sixty-four point five% 64.5% of the street vendors had running water which they used for handwashing. 35.5% of them used a small table cloth to wipe their hands with. The tablecloth is continually used many times before it is dipped in the used water. This is a source of cross-contamination. All of the street vendors also handled money and at the same time handling food without doing any hand washing. According to Akabanda et al. [35] improper hygiene practices like washing hands with contaminated water or without soap or reusing the wet cloth may cause food poisoning due to contamination of food. The use of gloves is also recommended [10,11].

**Fig. 3. The condition of water used to clean the fish before frying**

*3.3.1.5 Pests and rodents*

Ninety-three point five (93.5%) of the vendors admitted to having experienced frequent observations of pests and rodents at the vendors' site. 6.5% do not experience any pests. The pests experienced by the vendors were cockroaches (22.65), rodents (51.6%) were rats that were found at the sites occasionally. 22.6% of the vendors experience both rodents and cockroaches. Flies were observed at 100% of the vending sites.

Pests and rodents are known to be carriers of vectors that cause diseases. Pest rodents infesting or entering food products are a source of physical and microbiological hazards. The use of rodenticides and careless storage could also result in chemical hazards to prevent these food hazards, one needs to put in place good hygiene practices [36] Cockroaches have been recognized as a source of indoor allergens [37].

*3.3.1.6 Waste disposal*

Eighty point six (80.6%) of the vendors state that their wastes are collected by garbage collectors. 19.4% stated that they do burn their wastes. Through observation at heaps of garbage situated nearby. This has led to the development of breeding sites for flies, pests and rodents. Other hazards also result from such garbage disposal. Lack of disposal facilities for wastewaters, drainage and garbage allows the accumulation of garbage which acts as a reservoir for microorganisms that cause enteric diseases. They also act as a harborage for pests. It has been observed that street vending harms urban cleanliness quality and urban metropolis. Wastes generated by street vendors may lead to interference with city infrastructure. This includes the blocking of drainages which lead to unwarranted floods which shortens the lifespan of roads [30] (Ghatak and Chatterjee, 2018).

It was observed by the study that 61.3% of the street vendors use sanitary facilities that belong to their neighbors like hotels, butcheries, supermarkets. 22.6% of the students use public toilets. The sanitary facilities were unavailable at the vending sites. 16.1% stated that they do go back home to use their sanitary facilities. Inadequate sanitary facilities have been identified by Cortese et al. [20] to be a factor that affects food safety.

## 3.4 Microbial Contamination of the Deep-fried Fish as Served

### 3.4.1 Total coliforms contamination of the fish

Bacterial growth is a major cause of food spoilage and public health concern. In this study, Njiru ward has the highest overall mean as shown in Table 4. Clay city has the lowest overall mean of total coliforms. This may be because clean water is more available in clay city ward than in the other 4 wards where its availability is limited.

According to KS 1399-1: 2012 Specifications for Fresh and frozen whole fish, the Total Coliforms should not exceed 100cfu/g which is 2 in log form. From the results, it is observed that the fish gets contaminated through the handling process which leads to the concentration being higher than 100cfu/g.

Population growth and urbanization have led to environmental problems which lead to pollution of water sources. The presence of coliforms is a sign of fecal contamination and the existence of other intestinal pathogens [38]. This may also be due to secondary contamination through contact with contaminated equipment, poor personal hygiene or even lack of proper sanitary facilities. It is therefore practical to employ Good Hygiene practices to reduce the risk that may arise from secondary contamination. The utensils are placed carelessly on the ground and anywhere else and back to handle the ready to eat foods when the need arises. The fact that the vending sites are located next to sewage drainages is also a source of contamination [39].

The most contaminated part of the fish is the gills as seen in Table 4. Gills are known to be the route of infection by different causative agents including bacteria [40]. The least contaminated parts of the fish are the muscle, this is because it is the least handled part of the fish when preparing it. Vendors preferably handle the fish by holding the fins and the head.

The total coliforms concentration was significantly different p ($<0.05$) as the p-value was 0.003.

**Table 4. Total coliforms concentration by part of fish and Ward (Log 10 cfu/g)**

| Part of fish/ward | Head | Gills | Muscle | Fins | Mean |
|---|---|---|---|---|---|
| Kasarani | 2.46 ± 1.03 | 2.57± 0.89 | 0.83 ± 1.43 | 1.47 ± 1.29 | 1.83 ± 1.26 |
| Clay city | 1.46 ± 1.00 | 1.84 ± 0.22 | 0.92 ± 1.10 | 1.60 ± 1.27 | 1.45 ± 0.95 |
| Mwiki | 2.36 ± 0.86 | 3.10 ± 0.70 | 2.41 ± 1.19 | 2.22 ± 1.15 | 2.50 ± 0.91 |
| Njiru | 2.74 ±0.46 | 3.28 ± 0.67 | 3.19 ± 0.75 | 2.63 ± 0.67 | 2.89 ± 0.75 |
| Ruai | 2.36 ± 0.67 | 2.73 ± 0.35 | 2.13±1.99 | 2.11 ± 0.70 | 2.33 ± 0.99 |
| Mean | 2.22 ± 0.87 | 2.63 ± 0.74 | 1.83 ± 1.50 | 1.93 ± 0.99 | 2.15 ± 1.09 |

#### 3.4.2 *Staphylococcus aureus* contamination

In the study, the overall mean of *Staphylococcus aureus* as shown in Table 5 is below what is recommended in the standard KS 1399-1: 2012 Specifications for Fresh and frozen whole fish which is 100 CFUs/g converted to logarithm is 2. The enumeration was carried out according to KS 05-220: Kenya Standards for the Microbiological Examination of Food. The most contaminated part of the fish is the gills, followed by the muscle then the head (1.7019 ± 1.09) and the fins (1.5325 ± 1.06) are less contaminated. The ward with the highest contamination was Clay city ward (2.4569 ± 0.43). The ward with the least contamination was Mwiki ward (1.2808 ± 1.17).

According to Correia et al*.,* 2019, commercial processing of tilapia, water, environmental factors and handling provide favorable conditions for the growth of enterotoxigenic bacteria. Contamination with *Staphylococcus aureus* is due to inappropriate handling and this may lead to food poisoning of consumers. Contamination from the skin, mouth or nose of the handlers can be introduced directly into the food by process line workers and coming into contact with the food or by coughing and sneezing. An improper storage system is also a source of contamination (Joe et al., 2018; Sina et al., 2019) The *Staphylococcus aureus* concentration in the fish sample was significantly different between the different wards as $p<0.05$ as it was 0.043.

### 3.5 Color and Viscosity of the Frying Oils

As stated by Nayak et al., 2016, deep-frying is one of the most common methods of food preparation and one of the oldest methods. To reduce expenses, the oil tends to be used repeatedly for frying. Repeated use of oil has become a common practice due to low awareness of the public about the bad effect of this practice. When the oil is heated repeatedly, it causes several oxidative and thermal reactions which may result in changes in the physical appearance which include increased viscosity and darkening in color which alter the fatty acid composition of the oil.

#### 3.5.1 Color of the deep-frying oil

The results of color measurements of the frying oils are presented in Table 6, in terms of tintometer values and the Ward in the Sub-county.

The tintometer values are as follows: L (lightness), a (greenness-redness), b (yellowness), h (hue angle), c (chroma) values According to Manjunatha et al*.,* 2019 these parameters are affected by the frying time as well as the frying temperature. A low 'L' value (0-50) indicates dark, all samples fall below 50 and are therefore classified as dark. However, Kasarani ward vendors have the darkest oil (29.01 ± 4.13) which shows more repeated use of the oil. Vendors from Clay City had the lightest oil (38.96 ± 1.39). A positive 'a' value indicates a red color. Oil from Ruai ward (13.71 ± 0.89) displayed redder than the rest of the wards. The least red samples were from Clay City ward (0.90 ± 0.30). A positive 'b' value indicates yellow color. Oil from Mwiki ward displayed the highest yellow value (17.83 ±23.13) while clay city displayed the lowest (0.7525 ± 0.28). Chroma is considered as the quantitative attribute of colorfulness while hue is regarded as the qualitative attribute.

#### 3.5.2 The viscosity of the deep-frying oil

Viscosity is related to the chemical properties of the oil such as the chain length. (Zahir et al., 2017) Samples from Clay City ward have the highest viscosity (145.5 ± 3.11) this would indicate that the oil has been reused repeatedly compared to the other wards. Kasarani ward had samples with the lowest viscosity (111.75 ± 2.99) as shown in Table 7.

**Table 5. *Staphylococcus aureus* concentration in deep-fried fish by part of fish and Ward (Log 10 cfu/g)**

| Part of the fish/wards | Head | Gills | Muscle | Fins | Mean |
|---|---|---|---|---|---|
| Kasarani | 1.34 ± 1.36 | 1.72 ± 1.51 | 2.12 ± 0.19 | 1.38± 1.20 | 1.64 ± 1.06 |
| Clay city | 2.28 ± 0.19 | 2.56 ± 0.13 | 2.57 ± 0.85 | 2.42 ± 0.24 | 2.46 ± 0.43 |
| Mwiki | 0.53 ± 0.92 | 2.29 ± 0.54 | 1.52 ± 1.33 | 0.78 ± 1.35 | 1.28 ± 1.17 |
| Njiru | 2.53 ±0.46 | 2.49 ± 0.32 | 1.44 ± 1.25 | 1.35 ± 1.17 | 1.96 ± 0.97 |
| Ruai | 1.61 ± 1.40 | 2.79 ± 0.79 | 1.83 ± 1.75 | 1.43 ± 1.25 | 1.92 ± 1.27 |
| Mean | 1.70 ± 1.09 | 2.38 ± 0.76 | 1.94 ± 1.09 | 1.53 ± 1.06 | 1.89 ± 1.04 |

**Table 6. Frying oil color levels by color meter value and ward**

| Tintometer value ward | Color meter values | | | | |
|---|---|---|---|---|---|
| | A | L | B | H | C |
| Kasarani | 4.91± 4.99 | 29.01 ± 4.13 | 4.98 ± 4.20 | 44.60 ± 11.29 | 7.17± 6.40 |
| Clay City | 0.90 ± 0.30 | 38.96 ± 1.39 | 0.75 ± 0.28 | 40.22 ± 7.94 | 1.18 ± 0.39 |
| Mwiki | 9.61 ± 8.57 | 33.85 ± 5.35 | 17.83 ±23.13 | 51.2 ± 17.58 | 20.61 ± 24.22 |
| Njiru | 2.97 ± 1.66 | 31.42 ± 7.40 | 1.68 ± 1.03 | 31.04 ± 15.64 | 3.47 ± 1.79 |
| Ruai | 13.71 ± 0.89 | 38.86 ± 9.8 | 16.72 ± 17.05 | 40.32 ± 19.74 | 23.61 ± 12.53 |
| Total | 6.08 ± 6.09 | 34.70± 6.60 | 7.92 ± 13.07 | 41.40 ± 16.27 | 10.58 13.97 |

**Table 7. Mean frying oil viscosity over the wards**

| Ward | Mean centistokes (cSt) |
|---|---|
| Kasarani | 111.75 ± 2.99 |
| Clay City | 145.5 ± 3.11 |
| Mwiki | 135.5 ± 4.2 |
| Njiru | 114.75 ± 4.03 |
| Ruai | 119.25 ± 3.10 |
| Total | 125.35 ± 2.79 |

In a small domestic fryer like the one used in this case where the oil is repeatedly used, due to the large surface area, when the oil cools during storage for use the following day, it absorbs some oxygen from the atmosphere and gets oxidized. The oxidation leads to the development of low molecular weight degradation products which are volatile and some of them contribute to the off-flavors of the spent oil. Also, the oxidation is accompanied by polymerization into complex compounds containing conjugated bonds in their structures. Increased accumulation of these polymers leads to increased darkening of the oil color and viscosity. Cyclic polymeric substances form and they are carcinogenic [41]. The darkened oil also discolors the fish being fried which also becomes dark.

## 4. CONCLUSION

The vendor and environmental hygiene are wanting as the vending practices were generally found to be unsanitary across the chain from the sourcing of the raw fish to the point of selling the deep-fried fish. This is due to their lack of formal training in food safety. The fish consequently was found to be contaminated with total coliforms which would indicate fecal contamination and *Staphylococcus aureus* indicating poor hygiene. The deep-frying oil was also characterized by dark color and high viscosity which is an indication of prolonged usage which would lead to oxidation. The objective of the study was achieved as indicated.

## 5. RECOMMENDATION

Further studies on the quality and safety of the frying oil need to be carried out as most vendors reuse the oil several times. Government to strengthen policies and proper enforcement would help reduce the hazards likely from the poor handling of the fish and other street foods. The vending environment being better organized in terms of confinement premises, hygiene and sanitation would prevent contamination during

the preparation of the fish. Providing a specific market for fish vending would help to prevent cross-contamination. This being supplemented with the training of the vendors on food safety and quality would help prevent food hazards.

## DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon request.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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