Coliform contamination in Tilapia (*Oreochromis niloticus*) offered for sale at three local markets in Region Six, Guyana.

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ABSTRACT

Freshwater fish from wild caught sources are an important source of protein for many residents of Guyana. The availability and safety of freshwater fish that is offered for sale in local markets is not subjected to microbiological quality checks, which raises questions about the safety of the fish as it is moves along the value chains. The purpose of this study was to investigate the incidence and levels of coliform contamination in tilapia *(Oreochromis niloticus)* obtained from three local markets in Region 6. In the absence of local microbiological standards for fish sold in local markets, the results were compared to the International Commission on Microbiological Specification of Food (ICMSF) standard. The results indicated that the coliform levels in the tilapia often exceeded the ICMSF standard of <100MPN/g for total coliform and <10MPN/g for fecal coliform and *Escherichia coli.* Based on an ANOVA, the results showed that there was no significant difference at the $p<0.05$ among samples and markets and for Total Coliform, fecal and *E. coli* levels. Compared against the U.S FDA, EPA Acceptable level and ICMSF standards, the samples of fish that were offered for sale at the three local markets were not of acceptable standard. This speaks to the fact that there could be potential public health risks to consumers of the fish. There is an urgent need for local microbiological standards for fish sold at local markets to be developed.

Keywords: Total coliform, fecal coliform, *E. coli*, *O. niloticus*, Guyana

1. Introduction

For most of the world's population, fish products are important sources of protein [1] and worldwide, fish provides at least fifteen percent of the average per capita intake of animal protein for many persons [8]. In Guyana, wild caught freshwater fish is an important source of protein for many residents. However, the safety of freshwater fish that is offered for sale in local markets is not subjected to microbiological quality checks, which raises questions about public health safety concerns as the fish moves from harvester to consumer.

The quality of the aquatic environment in the surrounding area depends on the safety and microbiological quality of freshly caught fish. Fish from freshwater environments are susceptible to contamination, especially those with slow exchange of water and anthropogenic contamination [15].

Food microbiology is a study of microorganisms that affect both the quality and safety of raw and processed meat, poultry and egg products [16]. A number of deaths from numerous bacterial strains have been reported in the results of scientific research across the globe [21]. Pathogens which include viruses, fungi and even parasites are capable of causing food-borne infections from fish and fishery products. However, some commonly known species of biological risks include *Escherichia coli* (*E. coli*), *Salmonella*, coliform and *Staphylococcus aureus* [21].

Microorganisms grow when sanitation is poor and bacteria can be transmitted to humans through contact with infected food or water, during handling, processing, transportation by the food handler [17]. Bacteria grow in all types of environments and too many bacteria being present can result in the formation of toxins. The biggest problem involves improper safety practices and proper handling practices that cause food poisoning, the leading human exterminator [8].

Fishery products have been implicated in foodborne disease outbreaks and although overall food safety has improved dramatically, progress is uneven and outbreaks caused by food from microbial contamination, toxins and chemicals are still common [22]. Studies have reported outbreaks associated with seafood (including aquaculture products) [5] and landed fish and fish products are also lost due to microbial contamination [22].
On the coastal plain of Guyana, where marine fish is readily available, there still is a preference for freshwater fish species such as tilapia (*O. niloticus*). In inland areas where there is a limited availability of marine fish, freshwater fish, plays an important part in the diet of the local population [9].

The aquatic environment is extremely vulnerable to pollution from domestic, industrial and agricultural discharges, contamination from soil and airborne infections [19]. Fishes and other aquatic life forms are prone to environmental hazards and consumers ought to be concerned about the hygienic quality of market fishes [3].

Freshwater fish species sold in markets along the coast of Guyana are not always obtained from monitored aquaculture facilities but most times much of the fish being sold are wild caught. This suggests that there is hardly any direct control of the habitats from where these fish are harvested. The possibility therefore exists that fish offered for sale and local consumption will be harvested from waterways where the water quality, habitat quality and other environmental aspects are potential sources of microbiological contamination.

When assessing fish quality, the freshness of the fish is the most important feature. A number of post-mortem changes take place after the death of the fish. These changes are often linked to the growth of microorganisms that are either linked to contamination during the processes of harvesting or handling [22].

Most of the areas in Region 6 that are used for harvesting freshwater fish for sale local markets or for local consumption, are often in close proximity to agriculture farms. Being in such close proximity can potentially impact the quality of the aquatic environment and the quality of the fish. Potential coliform contamination, impact from the use of agricultural chemicals and insanitary and improper waste disposal are among the main factors that can affect water ways and pose threats to both the aquatic medium and fishes in the environment [7]. Further, it was observed that storage facilities and fish handling processes at the local markets were poor. When local markets that offer fish for sale have poor storage and handling facilities, there is usually a high incidence of microbial contamination [23].

2. Justification for study

In Guyana, tilapia, a freshwater fish, is a major source of protein and this is sold in large quantities at local markets [19]. While some of the fish that is sold is reared in fish ponds, much is usually wild caught from different water bodies. The aquatic environment is vulnerable to many risk factors because of their proximity to agricultural farms and residential communities. Also, the increase in the use of agricultural chemicals and the improper sanitary disposal of wastes pose a threat to the aquatic environment [3].

Quite often the transportation and handling of the fish for sale leaves much to be desired and local community markets in Guyana do not always have appropriate cold storage facilities for the fishes that are being sold. These conditions make the fish being offered for sale vulnerable to contamination with bacteria since these microorganisms thrive when they are not handled or stored properly [19].

This research was done to investigate the incidence and level of coliform contamination of tilapia (*Oreochromis niloticus*) offered for sale at three local markets in Region Six. The following research questions were addressed in this study:

1. Are total coliform, fecal coliform and *E. coli* present in tilapia offered for sale at local markets in Region 6?
2. Is there a significant difference between the total coliform, fecal coliform and *E. coli* found in tilapia obtained from three local markets in region 6?
3. Are the levels of coliform contamination in tilapia sold in three local markets in Region 6 within acceptable standards?

The hypotheses that guided the study were:

Null Hypotheses

1. **H_0**: Total coliform, fecal coliform and *Escherichia coli* are not found in tilapia from local markets in Region 6.
2. **H_0**: There is no significant difference between total coliform, fecal coliform and *Escherichia coli* found in tilapia from local markets in Region 6.
3. **H_0**: The coliform bacterial levels in tilapia offered for sale at the local markets in Region 6 is not below acceptable standards.
4. **H_0:** There is no difference in the total coliform, fecal coliform and *Escherichia coli* content in different parts of the tilapia.

Alternate Hypotheses

1. **H_a**: Total coliform, fecal coliform and *Escherichia coli* are found in tilapia from local markets in Region 6.
2. **H_a**: There is a significant difference between total coliform, fecal coliform and *Escherichia coli* found in tilapia from local markets in Region 6.
3. **H_a**: The coliform bacterial levels in tilapia offered for sale at the local markets in Region 6 is below acceptable standards.
4. **Ha**: There is a difference in the total coliform, fecal coliform and *Escherichia coli* content in different parts of the tilapia.

3. Materials and Method

3.1 Study Locations

The present study was conducted to investigate the incidence and level of coliform contamination of tilapia (*Oreochromis niloticus*) obtained from three local markets in Region Six. Fish samples for conducting this study were obtained from the Rose Hall, Port Mourant and Skeldon markets.

3.2 Collection of Tilapia from the Local Markets

A total of nine (9) tilapia fishes were obtained (three were collected once from each market) between 7:30 a.m. and 9:30 a.m. Eighteen (18) fish samples were obtained within two days (February 18th and March 18th, 2019). Each fish was collected with a sterile glove, stored in a sterile plastic bag, placed under ice, and then transported to the University of Guyana, Berbice Campus for sample preparation.

3.3 Fish Sample Preparation

Samples were prepared by removing approximately 25 grams of the muscle, skin and gut [11]. This was done using aseptic techniques. The scales were removed with a sterilized knife then the skin was removed from the right side of fish behind the dorsal fin. Muscle samples were collected through incision on the same side and section of the fish body. A sterile scalpel was used to open the body cavity to remove a small portion of the gut. A scissor, scalpel and knife were used to remove the layers. After removal, each layer was placed in sterile plastic bags and transported to the laboratory for microbiological analysis [11].

3.4 Blending and Dilution of Samples

In a blender jar containing 25g analytical unit, 225 ml of Butterfield's phosphate-buffered dilution water was added and mixed for 2 minutes [10].

3.5 Serial Dilution

This resulted in a dilution of 10^{-1}. Pipets were used to dilute the original. All decimal dilutions were prepared with a sterile diluent of 90 ml plus 10 ml of previous dilution. The dilutions that were prepared are 10^{-1}, $^{10-2}$ and 10^{-3}. All dilutions were shaken vigorously in 7 seconds, 25 times in an arc of 30 cm [10]. Dilutions were made in triplicates for total coliform, fecal coliform and *E. coli* MPN tests.

3.6 Microbiological Analysis of Fish Samples

In order to determine the incidence and level of total coliform, fecal coliform and *E. coli* contamination in *O. niloticus*, microbiological analysis was carried out using the previously established method recommended by the GA-FDD.

The method that was used to detect total coliforms, fecal coliforms and *E. coli* was the enumeration method (MPN method) which is based on lactose fermentation. The Most Probable Number (MPN) method is a statistical, multi-stage assay consisting of three phases. The presumptive, confirmed and completed phases. In these phases, serial sample dilutions are inoculated into a broth medium [10]. In coliform and fecal coliform analysis, the first two phases are performed, while all three phases are performed for *E. coli* [10] [3]. The number of positive gas tubes (fermentation of lactose) were assessed, from which the other two phases of the test are carried out, and then used the combination of positive results to consult the statistical table in order to estimate the number of organisms that were present [10].

3.7 Statistical Analysis

The data obtained from the samples collected at Rose Hall, Port Mourant and Skeldon markets were subjected to statistical analysis, Analysis of Variance test (ANOVA) Two Factor without replication using the SPSS (Statistical Package for the Social Sciences) software version 23. In the absence of local standards, the results from the assessment were compared to the Standard of United States (U.S.) Food and Drug (FDA) & Environmental Protection Agency (EPA) safety levels in regulation and guidance for fish and fisheries product [10] [11] [6].

4. Results

4.1 Mean length-weight dynamics in fish samples

Three (3) fishes (*O. niloticus*) were collected once from each market during February and March, 2019 and length, weight and weight-length ratio measurements were taken (Table 1).

Table 1. Mean length and weight relationships of *O. niloticus* obtained from Skeldon, Port Mourant and Rose Hall markets.

	Skeldon			**Port Mourant**			**Rose Hall**		
	Mean Length (cm)	**Mean Weight (g)**	**Mean Weight Length Ratio**	**Mean Length (cm)**	**Mean Weight (g)**	**Mean Weight Length Ratio**	**Mean Length (cm)**	**Mean Weight (g)**	**Mean Weight Length Ratio**
February	17.9	95.0	5:1	21.8	185.0	9:1	16.2	73.6	5:1
March	21.4	173.3	8:1	23.7	237	10:1	21.5	175	8:1

For the month of February, fish samples collected from the Port Mourant market had the highest mean weight-length ratio and samples from Skeldon and Rose Hall both had the same mean weight-length ratio. For the month of March, fish samples collected from the Port Mourant market had the highest mean weight-length ratio and samples from Skeldon and Rose Hall both had the same mean weight-length ratio (Table 1).

A low standard deviation is usually indicative of the fact that data points are very close to the mean while a high standard deviation is indicative that the data points are spread out over a large range of values. In this study the results obtained revealed that the standard deviation of the length and the weight of fish samples did not deviate from the mean and the data points were within a close range.

4.2 Total coliform in fish samples

Tissue samples of the skin, muscle and intestine of the fish (*O. niloticus)* obtained from the three markets in Region 6 during the months of February and March were tested for Total Coliform, Fecal Coliform and *Escherichia coli* (*E. coli*). On the basis of the results from the investigation (Table 2) it was revealed that there was some contamination of the fish samples.

Table 2 Mean Total and Fecal Coliform and *E. coli* on skin, muscle and intestine samples.
(Each value is the mean of triplicate readings obtained from three fish samples)

		Skeldon		Port Mourant		Rose Hall	
		February	**March**	**February**	**March**	**February**	**March**
Total Coliform	**Skin**	9.2 MPN/g	1100 MPN/g	7.4 MPN/g	1110 MPN/g	28 MPN/g	1110 MPN/g
	Muscle Tissue	29 MPN/g	53 MPN/g	2.9 MPN/g	1110 MPN/g	3.6 MPN/g	460 MPN/g
	Intestine	7.4 MPN/g	290 MPN/g	23 MPN/g	2.9 MPN/g	35 MPN/g	460 MPN/g
Fecal Coliform	**Skin**	3.6 MPN/g	7.4 MPN/g	3.6 MPN/g	460 MPN/g	3.6 MPN/g	9.2 MPN/g
	Muscle Tissue	2.9 MPN/g	3.6 MPN/g	2.9 MPN/g	460 MPN/g	2.9 MPN/g	460 MPN/g
	Intestine	2.9 MPN/g	290 MPN/g	2.9 MPN/g	93 MPN/g	3.6 MPN/g	460 MPN/g
E. coli	**Skin**	3.6 MPN/g	7.4 MPN/g	3.6 MPN/g	2.9 MPN/g	2.9 MPN/g	2.9 MPN/g
	Muscle Tissue	2.9 MPN/g	3.6 MPN/g	2.9 MPN/g	460 MPN/g	2.9 MPN/g	2.9 MPN/g
	Intestine	2.9 MPN/g	2.9 MPN/g	2.9 MPN/g	93 MPN/g	3.6 MPN/g	2.9 MPN/g

It can be seen that the tilapia (*O. niloticus)* obtained from local markets in Region 6 were of better quality in February when compared to that of March. This may be interpreted as an indication that the environment from which the tilapia was obtained during the month of March was most likely more contaminated than the environment from which the tilapia came from during the month of February. Also, it may have been as a result of poor and improper handling and storage procedures that were used in March as compared to that of February.

The Total Coliform present on the different parts of the fish (tilapia) obtained from the three local markets in Region 6 are presented in Table 3 which also shows the specified International Commission on Microbiological Specification of Food (ICMSF) standard. This standard was used for reference and comparison since no such standard was available for Guyana.

Table 3 Mean Total Coliform present on the skin, muscle and intestine of tilapia obtained from three local markets in Region 6.

		Skin	Muscle Tissue	Intestine	Specification (ICMSF Standard)
Skeldon	**February**	9.2 MPN/g	29 MPN/g	7.4 MPN/g	<100MPN/g
	March	1100 MPN/g	53 MPN/g	290 MPN/g	<100MPN/g
Port Mourant	**February**	7.4 MPN/g	2.9 MPN/g	23 MPN/g	<100MPN/g
	March	1110 MPN/g	1110 MPN/g	1110 MPN/g	<100MPN/g
Rose Hall	**February**	28 MPN/g	3.6 MPN/g	460 MPN/g	<100MPN/g
	March	1110 MPN/g	35 MPN/g	460 MPN/g	<100MPN/g

Overall, Total Coliform in the skin (1110MPN/g) and muscle (290MPN/g) samples exceeded the ICMSF standard safety levels for total coliform. During the month of February, the results show that the Total Coliform in the skin from fish samples collected all three markets was below the ICMSF standard. Total Coliform in muscle tissue samples from fish collected at all three markets was below the ICMSF standard. Total Coliform in intestine tissue samples from fish from Rose Hall market (460 MPN/g) was the only one that exceeded the ICMFS standard.

During the month of March, the results show that the Total Coliform in the skin from fish samples collected at all three markets was between 1100MPN/g and 1100MPN/g which exceeded the ICMSF standard of <100MPN/g. Muscle tissue sample from one market, Port Mourant, was 1110MPN/ which exceeded the ICMSF standard. Total Coliform in intestine tissue samples from fish collected at all three markets (Skeldon, 290 MPN/g; Port Mourant, 1110 MPN/g and Rose Hall, 460 MPN/g) all exceeded the ICMFS standard.

The Data was subjected to ANOVA One Factor analysis without replication for the Total Coliform count of *O. niloticus* at all three markets. The p value (0.54786) was greater than 0.05. The *f*-ratio value was 0.62653. These values indicate that the result is *not* significant at $p < .05$.

4.3 Fecal coliform levels in fish samples

The level of fecal coliform present on the different parts of the fish (*O. niloticus*) samples obtained from the three local markets in Region 6 was also investigated (Table 4). It can be seen that for the most part, all of the samples from all the tested parts of the fish (skin, muscle and intestine) had fecal coliform levels that were below the ICMSF standard of <10MPN/g during the two sample periods in February and March.

Table 4 Mean Fecal Coliform in skin, muscle and intestine samples of tilapia obtained from three local markets in Region 6.

		Skin	Muscle Tissue	Intestine	Specification (ICMSF Standard)
Skeldon	**February**	3.6 MPN/g	2.9 MPN/g	2.9 MPN/g	<10MPN/g
	March	7.4 MPN/g	3.6 MPN/g	290 MPN/g	<10MPN/g
Port Mourant	**February**	3.6 MPN/g	2.9 MPN/g	2.9 MPN/g	<10MPN/g
	March	460MPN/g	460 MPN/g	93 MPN/g	<10MPN/g
Rose Hall	**February**	3.6MPN/g	2.9 MPN/g	3.6MPN/g	<10MPN/g
	March	9.2 MPN/g	460 MPN/g	460 MPN/g	<10MPN/g

The exceptions and instances when the fecal coliform content was higher than the ICMSF standard were during the month of March for samples from Port Mourant, when all samples from the different parts of the fish were higher than the ICMSF standard. In these cases, the fecal coliform levels were, skin samples (460 MPN/g), muscle (460 MPN/g) and intestine (93 MPN/g). Also, in March for intestine samples from Skeldon, the fecal coliform level was 290 MPN/g and in march, samples from the muscle and intestine from Rose Hall had a fecal coliform level of 460 MPN/g. The Data was subjected to ANOVA One Factor analysis without replication for the Total fecal coliform count of *O. niloticus* at all three markets. The p value was 0.803585 and the *f*-ratio value was 0.22189. These values indicate that the result is *not* significant at $p < .05$.

4.4 *E. coli* levels in fish samples

Table 5 gives the results of the investigation for the level of *E. coli* in the samples of the fish (*O. niloticus*) obtained from the three local markets in Region 6 for the two months. There was no significant difference in the monthly mean *E. coli* levels (The *p*-value is .243016. The *f*-ratio value is 1.46954. The result is *not* significant at $p < .05$).

Table 5 Mean *E. coli* levels in skin, muscle and intestine of tilapia from three local markets in Region 6.

		Skin	Muscle Tissue	Intestine	Specification (ICMSF Standard)
Skeldon	**February**	3.6 MPN/g	2.9 MPN/g	2.9 MPN/g	<10MPN/g
	March	7.4 MPN/g	3.6 MPN/g	2.9 MPN/g	<10MPN/g
Port Mourant	**February**	3.6 MPN/g	2.9 MPN/g	2.9 MPN/g	<10MPN/g
	March	2.9 MPN/g	460 MPN/g	93 MPN/g	<10MPN/g
Rose Hall	**February**	2.9 MPN/g	2.9 MPN/g	3.6 MPN/g	<10MPN/g
	March	2.9 MPN/g	2.9 MPN/g	2.9 MPN/g	<10MPN/g

The results show that there were two instances where the levels of *E. coli* were higher than the ICMSF standard. These two instances were in March when the muscle sample had 460 MPN/g and the intestine sample had an *E. coli* level of 93 MPN/g. When the mean *E. coli* levels for the entire sampling period were combined, the result of the ANOVA One Factor analysis without replication for *E. coli* was not significant at $p < .05$. The p value was 0.485084 and the f-ratio value was 0.75511. Figure 1 shows the combined results for Total Coliform, Fecal Coliform and *E. coli* present in tilapia obtained from three local markets in Region 6.

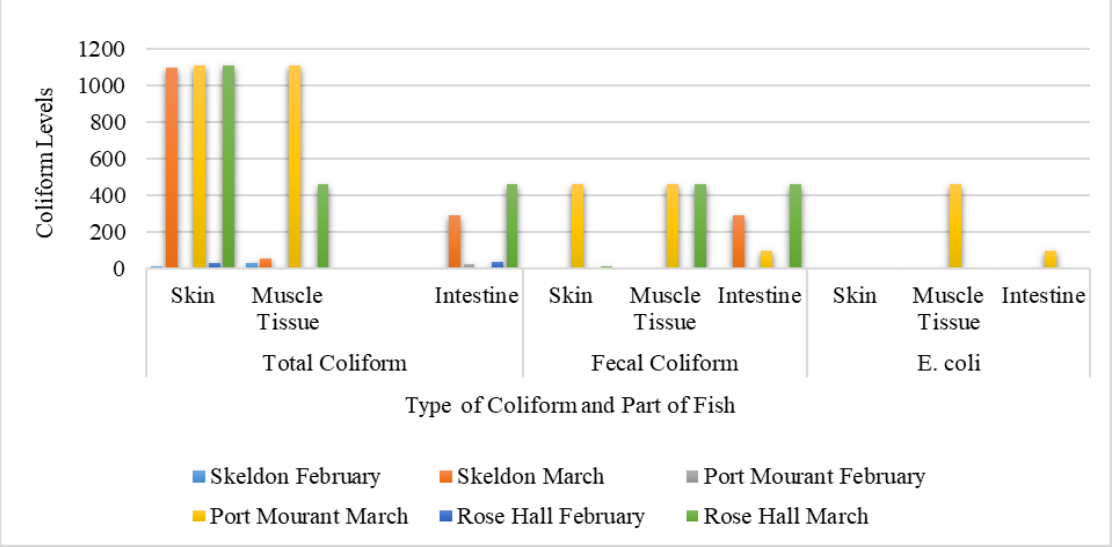

Figure 1 Total coliform, fecal coliform and *E. coli* in *O. niloticus* from three local markets in Region 6

5. Discussion

If an effective evaluation of the results of microbiological analysis in fish is to be conducted, local standards are necessary. However, there are no such available standards in Guyana for the microbiological quality of fish sold in markets. As a result, for this research, the International Commission on Microbiological Specification for Foods (ICMSF) standard for safety levels used by the United States (U.S.) Food and Drug (FDA) and Environmental Protection Agency (EPA) for total coliform, fecal coliform and *E. coli* were used.

The specified limit for total coliform is <100MPN/g whereas, the specified limit for fecal coliform and *E. coli* is <10MPN/g. The results from this study showed that the coliform levels of *O. niloticus* often surpassed the U.S FDA & EPA microbiological standard. The Null hypothesis that the coliform levels in tilapia offered for sale at the local markets in Region 6 was not below acceptable standards was not accepted.

The Food and Drug Administration proposed that if such methods fulfil the regulation, any alternative method could be used to satisfy the regulation. For total coliform, fecal coliform and *E. coli*, the method used by U.S. FDA and EPA to estimate the bacterial count of the United States organization's safety levels in regulating and guidance was the Most Probable Number (MPN).

From the tests done, it can be inferred that total coliform, fecal coliform and *E. coli* are present in *O. niloticus* (tilapia) offered for sale at local markets (Skeldon, Port Mourant and Rose Hall) in Region 6. It can also be inferred that the samples were more contaminated in March than in February. This may be an indication that the environment from which the tilapia was obtained during the month of March was most likely more contaminated than the environment from which the tilapia came from during the month of February. Also, it can be due to the handling and storage procedures that were used in March as compared to that of February. Further, the results are indicative that the tilapia offered for sale at Skeldon, Port Mourant and Rose Hall markets during the months of February and March were below acceptable standards and should not have been sold for consumption to consumers.

It is well established that freshwater fishes can harbour human pathogenic bacteria, especially from the coliform group [1]. Pathogenic isolates of bacteria such as total coliform, fecal coliform and *E. coli* present in fish offered for sale are organisms of interest in terms of public health concerns. The results of the test for total coliform is an indicator of water contamination which can also happen during various processing steps such as transportation and handling. In addition, the water used for washing or icing may also cause the contamination [20].

Fecal contamination is an indicator of sewage contamination, unsanitary processing and handling. However, the more accurate indicator of fecal contamination is *E. coli* [20]. The lower number of coliforms can be beneficial for indicating the effectiveness of safety procedures during processing and handling [20]. In the present study, the total coliforms count ranged from 2.9 MPN/g to 1110 MPN/g and fecal coliforms and *E. coli* counts ranged from 2.9 MPN/g to 460 MPN/g. Therefore, based on a comparison with the ICMSF, US – FDA and EPA standards, it can be said that the tilapia offered for sale at Skeldon, Port Mourant and Rose Hall markets during the sampling period were not of good quality since they were contaminated with coliforms (Table 6) and might have been potentially unsafe for consumption.

Table 6 Qualitative analysis for coliforms in *O. niloticus* from Skeldon, Port Mourant and Rose Hall markets

Qualitative analysis for Total coliform, Fecal coliform and *E. coli*						
Month sample taken						
February				**March**		
	Sampling Sites					
	Skeldon	Port Mourant	Rose Hall	Skeldon	Port Mourant	Rose Hall
	Occurrence			**Occurrence**		
Fish species	Total coliform	Fecal coliform	*E. coli*	Total coliform	Fecal coliform	*E. coli*
O. niloticus (Tilapia)	+	+	+	+	+	+

The question about the source of contamination therefore arises. Given that vendors purchase tilapia for sale from different persons who also harvest from different locations it is difficult to ascertain the specific source of harvesting. What may be inferred from the results is that it may be indicative that the samples were either probably harvested from contaminated aquatic habitats or the contamination may have occurred if fish handlers did not maintain aseptic conditions throughout the handling processes and value chain.

[11] and [2] attributed such contamination to the fact that possible contamination may linked either to poor sanitation and handling practices of fish vendors or poor storage facilities. [1], [6] and [4] also stated that other than the microorganisms present on the fish at the time of capture, more can be added through unhygienic practices along with contaminated equipment and storage facilities.

Sample collection was done between 6:30 a.m. and 8:30 a.m. on **February 18, 2019 and March18, 2019**. At Skeldon, Port Mourant and Rose Hall markets, it was observed that the fishes (tilapia) were kept under ice in buckets and old refrigerators and were then placed on the counter to be offered for sale. No proper sanitary measures or precautions were taken by fish vendors when handling the fish in each market.

During the study vendors stated that the fishermen from whom they purchase their fish supplies, would usually transport the fish to the markets without ice placed on the fishes. It is a known fact that fish is highly perishable and begins to spoil very soon after death. The use of ice is important for reducing the temperature thereby controlling the proliferation of microorganisms which are responsible for the deterioration [13] [12]. The use of ice on fish during transportation and storage, therefore, can increase the shelf life of the fish and reduce the threat of spoilage [12] [14] and ultimately increase the likelihood that the transported fish is safe and of a better quality for consumers.

Since, total coliform, fecal coliform and *E. coli* do not belong to the normal microbiota of fishes. It may be inferred that their presence may most likely have been associated with contamination of the fishing location or improper handling in the production and transport chain, including the ice, equipment and tools that come into contact with the fish [18] [24].

6. Conclusions

The results of this research indicate that total coliform, fecal coliform and *E. coli* were present in *O. niloticus* (tilapia) samples obtained from the three local markets. Therefore, H_0 (Total coliform, fecal coliform and *Escherichia coli* are not found in tilapia from local markets in Region 6) was not accepted.

The fish samples were below the acceptable standards to consume since the observed microbial loads often exceeded the U.S Food and Drug Association (FDA) and Environmental Protection Agency (EPA) recommended levels which is the International Commission on Microbiological Specifications of Food (ICMSF standard). Hence, the Alternate hypothesis H_a: (The coliform bacterial levels in tilapia offered for sale at the local markets in Region 6 is below acceptable standards) was accepted.

There was no significant difference between the total coliform, fecal coliform and *E. coli* found in tilapia from local markets in Region 6. Therefore, the Null hypothesis, H_0: (There is no significant difference between total coliform, fecal coliform and *Escherichia coli* found in tilapia from local markets in Region 6) was accepted.

There was no significant difference between the total coliform, fecal coliform and *E. coli* found in different parts of the fish. Therefore, the Null hypothesis, H_0**:** (There is no difference in the total coliform, fecal coliform and *Escherichia coli* content in different parts of the tilapia) was accepted.

7. Recommendations

Fish is a very important food staple in the diet of many coastland residents in Guyana so it should be a priority that the quality of fish offered for sale to consumers is high.

More research should be done in this area to develop a local standard that is acceptable for use and for monitoring of the quality of freshwater fish offered for sale at local markets in Guyana.

There is a need for a study to examine the microbial quality of fish from specific freshwater bodies to investigate the correlation of results of microbial load in fishes and the aquatic environment where the fishes are harvested.

Future studies should be designed to conduct this type of research in all ten administrative regions of Guyana to collect data to inform the development of a national standard for freshwater fish quality being sold at local markets.

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Conflict of Interest

None.

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