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RESEARCH ARTICLE

# Microbiological and Public Health Status of Cooked Meat and Fish in Ethiopia

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**Abstract:**

***Background:***

Due to poor sanitation practices and handling of food, weak regulatory systems, lack of resources and education for food-handlers, food-borne infections happen frequently and pose a serious threat to human health in developing countries like Ethiopia.

***Materials and Methods:***

A total of 265 samples of meat and fish with *berbere* spice added or not were collected from Ethiopia between Jan. 2013 to Dec. 2017. The food samples were analysed using colony count for Aerobic Colony Count (ACC) and *S. aureus,* spread method for yeasts and moulds enumeration, Nordic Committee on Food Analysis Method No. 44 for coliforms and ES ISO 6579:2002 for *Salmonella and Shigella* species. The data was analysed using SPSS 20.0.

***Results:***

The unsatisfactory levels for aerobic colony count, total and thermotolerant coliforms, *E. coli,* moulds and yeasts counts for the total samples were 12.1% (N=32), 11.7% (N=31), 1.9% (N=5), 3.4% (N=9), 1.2% (N=3) and 1.9% (N=5), respectively. Among the categories of three ready-to-eat foods examined, beef and mutton meats, fish and poultry, had the highest and lowest microbial contamination. Microbial quality of packaged samples with *berbere* spice added was reasonable compared with unpackaged samples with no *berbere* spice added.

***Conclusion:***

About 21% of the samples had unsatisfactory microbial quality because of aerobic colony count, coliforms or fungi. However, *Salmonella*, *Shigella* spp. and *S. aureus* were not detected in the samples tested. Processing under hygienic conditions, adding *berbere* spice to foods and packaging enhances the quality of ready to eat articles.

**Keywords:** *Berbere* spice, Cooked meats, Coliforms, Fish, Fungi, *E. coli*.

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|---|---|---|---|

## 1. INTRODUCTION

Food safety is a scientific discipline including handling, preparation, and storage of food. It is one of the most vital parts of food service processes but usually gets the least amount of attention and visibility [1]. However, the need for preparation and storage of foods throughout to ensure food safety has caused a lot of public concern [2]. Cooked food is a ready-to-eat commodity that is consumed without further processing [3, 4]. This food is provided by the catering business to the individuals and covers all parts of society such as hospitals, childcare, restaurants, bars, take-away and fast-food outlets, schools and nursing homes. This business has expanded to the highest degree due to lifestyle change, travelling and boosted purchasing power [5].

Illnesses due to microbes make microbial quality to be the most important aspect of food safety. Therefore, food safety predominantly focuses on the control of microbial contamination of foods [6]. The contamination of food by the microbes may pose a serious threat to human health [7].

More than half of the outbreaks attributable to foodborne

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diseases could be traced to poultry, beef and mutton meat products due to lack of good practices at restaurants, homes, institutions and in almost all instances [8]. Cooked meat and fish products can be classified as high- risk food and intermediate -risk foods, respectively [9]. Due to poor sanitation practices and handling of food, insufficient food safety laws, weak regulatory systems, lack of resources and education for food-handlers, food-borne infections frequently occur in underdeveloped countries like Ethiopia [10].

Food borne diseases are either infectious or toxic in nature and accountable for high levels of morbidity and mortality in population especially immunocompromised individuals, such as children and elderly [11]. The consumption of food contaminated by bacteria, fungi, toxins, viruses, and parasites may cause diseases [12]. More than 200 diseases spread through contaminated food, which infects millions of people who get sick and die every year. Diarrhea transmitted by consuming unsafe food alone kills about 1.5 million children annually [13]. Food borne illnesses can be avoided by controlling microbes at one or more phases of food production [14], a serious cause of individual distress, social disturbance, death and economic burden [15].

There is no sufficient food safety information with regard to ready-to-eat food in the world [16] including Ethiopia. Therefore, the objective of the current study was to examine the microbiological quality and safety of cooked meats and fish in some regions of Ethiopia using moulds, yeasts, Aerobic Colony Count (ACC), total and thermotolerant coliforms, *E. coli*, *S. aureus, Salmonella* and *Shigella* spp.

## 2. MATERIALS AND METHODS

### 2.1. Samples

A retrospective study was conducted on 265 food samples (209 packaged and 56 unpackaged) of sliced meat of cooked poultry (N=101), beef and mutton meat (N=96) with a spice, berbere (spice mix mainly red hot chilli) [17] added or not, and cooked fish (N=68) which were collected between January 2013 to December 2017.

The samples were collected from Addis Ababa (N=250), Oromia (N= 13), Gambela (N= 1), and *Southern Nations, Nationalities, and Peoples' Region* (SNNPR) (N=1) regional states of Ethiopia. The meats and fish samples were obtained from different premises, catering (N=240) and restaurants (N=25). The samples were transported on ice to the National Public Health Microbiology Research Laboratory of Ethiopian Public Health Institute. The samples were analyzed for mould, yeasts, ACC, total and thermotolerant coliforms, *E. coli* and *S. aureus* within 24 hours of collection.

### 2.2. Laboratory Methods

To process the sample, 25g of ready to eat food sample was mixed with 225 ml of buffered peptone water. Further decimal serial dilutions were performed up to $10^5$ as required in the same peptone water for bacteriological and mycological sample analyses.

#### *2.2.1. Aerobic Colony Count (ACC)*

The food samples were analyzed using plate count agar by incubating for 48 ± 3 hours at 30°C. The bacteria were enumerated as Colony-Forming Units per gram (CFU/g) [18].

#### *2.2.2. Yeasts and Moulds Enumeration*

Yeast and mould were counted according to ISO 7954 using Rose Bengal chloramphenicol agar spread method and incubated for 5-7 days at 25°C [19].

#### *2.2.3. Coliform Test*

Coliform test was conducted using the Nordic Committee on Food Analysis, NMKL Method No. 44. About 5 ml of tryptone soya agar was poured to 1 ml of 1:10 to $1:10^5$ diluted samples and pre-incubated for 1-2 hours at 20 - 25°C. Melted agar of violet red bile (10-15 ml) was added on top of the agar and typical colonies were enumerated after incubation at 37°C and 44.5°C for 24 hours. Five colonies from presumptive coliforms were confirmed by checking for the production of gas in brilliant green bile salt lactose broth and thermotolerant coliforms and *Escherichia coli (E. coli), Escherichia coli* (EC) broth was inoculated and incubated at 44.5 °C. The presence of gas indicated the occurrence of thermotolerant coliforms. *E. coli* was confirmed by indole test. Test results were reported by calculating the population density from the colonies enumerated and the degree of dilutions [20].

#### *2.2.4. Staphylococcus aureus (S. aureus) Enumeration*

Enumeration of *S. aureus* was taken place according to ES ISO 688-1:2002 using pour plate method on Baird-Parker agar or manitol salt agar and incubated for 24 hours at 37°C. The test was confirmed by coagulase test [21].

#### *2.2.5. Identification of Salmonella and Shigella species*

*Salmonella spp.* was tested by ES ISO 6579: 2002 using buffered peptone water pre-enrichment medium followed by selenite cystine and Rappaport vascildas broths selective enrichments and xylose lysine deoxycholate isolation medium incubated for 24 hours at 37°C. *Salmonella* presumptive colony was subcultured on plates and biochemically and serologically examined for confirmation [22]. For the detection of *Shigella* spp., the same culture media were used.

#### *2.2.6. Data Analysis*

The data was analyzed using SPSS 20.0 (SPSS Inc. Version 20, Chicago, Illinois). Probability value was set at p-value < 0.05. To test out data normality, Shapiro-Wilk test was used. The differences in microbes values by sample type, regions, analysis years, packaging status, catering type, spice added (*berbere)* were found using non parametric Kruskal-Wallis test. The Spearman Rank Correlation was to test the associations between various organisms.

## 3. RESULTS

A total of 265 cooked poultry meat, beef and mutton meats and fish samples were tested for bacterial and fungal contaminations. *Cooked food* samples, with ACC, total

coliform and thermotolerant coliforms, *E. coli* and moulds and yeasts counts in different ranges, have been indicated in Table **1**. None of the cooked poultry meat, beef and mutton meats and fish samples examined were in the category of unacceptable or potentially hazardous levels of microbial enumerations. All meats and fish samples were examined for full range of microbes, except *S. aureus,* which was only examined for 64 samples (27 poultry, 30 meats and 7 fish). *S. aureus, Shigella* and *Salmonella* spp. were not detected in any of the tested cooked food samples.

Packaged cooked meats and fish samples had ACC in the ranges of $<10^5$, $10^5$ - $<10^6$ and $\geq 10^6$ CFU/g were determined to be 75.1% (N=157), 14.4% (N=30) and 10.5% (N=22), respectively. Total and thermotolerant coliforms ranges, $<10^2$, $10^2$ - $<10^4$ and $\geq 10^4$ CFU/g for the samples were assessed to be 70.8% (N=148), 16.7% (N=35) and 12.4% (N=26); 92.8% (N=194), 12.4% (N=26% 0 and 1.4% (N=3) respectively. *E. coli* ranges, <20, 20 - $<10^2$ and $\geq$100CFU/g for the samples were reported to be 77.4% (N=2050, 1.4% (N=3) and 0.5% (N=1). Moulds and yeasts counted greater than $10^4$ CFU/g were noticed each in 1% (N=2) cooked food samples.

Unpackaged cooked meats and fish samples had ACC in the ranges of $<10^5$, $10^5$ - $<10^6$ and $\geq 10^6$ CFU/g were found to be 76.8% (N=43), 5.4% (N=3) and 17.9% (N=10) respectively. Total and thermotolerant coliforms ranges, $<10^2$, $10^2$ - $<10^4$ and $\geq 10^4$ CFU/g for the samples were observed to be 73.2% (N=41), 17.9% (N=10) and 8.9% (N=5); 83.9% (N=47), 12.5% (N=7%) and 3.6% (N=2) respectively. *E. coli* ranges, <20, 20 - $<10^2$ and $\geq$100CFU/g for the samples were determined to be 83.9% (N=47), 1.8% (N=1) and 14.3% (N=8). Moulds and yeasts greater than $10^4$ CFU/g were counted in 1.8% (N=1) and 5.4% (N=3) cooked food samples respectively.

Cooked meats and fish samples with *berbere* spice added had ACC in the ranges of $<10^5$, $10^5$ - $<10^6$ and $\geq 10^6$ CFU/g appeared to be 93.5% (N=29), 3.2% (N=1) and 3.2% (N=1) respectively. Total and thermotolerant coliforms ranges, $<10^2$, $10^2$ - $<10^4$ and $\geq 10^4$ CFU/g for the samples were investigated to be 90.3% (N=28), 9.7% (N=3) and 0%; 100% (N=31), 0% and 0%, respectively. *E. coli ranges*, <20, 20 - $<10^2$ an $\geq$100 CFU/g for the samples were recorded to be 100% (N=31), 0% and 0% respectively. Moulds and yeasts counts greater than $10^4$ CFU/g were noticed in 0% and 3.2% (N=1) of the cooked food samples, respectively.

Cooked poultry meats, beef and mutton meats and fish samples with *berbere* spice not added had ACC in the ranges of $<10^5$, $10^5$ - $<10^6$ and $>10^6$ CFU/g were evaluated to be 73.1% (N=171), 13.7% (N=32) and 13.2% (N=31) respectively. Total and thermotolerant coliforms ranges, $<10^2$, $10^2$ - $<10^4$ and $\geq 10^4$ CFU/g for the samples were tested to be 68.8% (N=161), 17.9% (N=42) and 13.2% (N=31); 89.7% (N=210), 8.1% (N=19) and 14.7% (N=5) respectively. *E. coli* ranges, <20, 20 - $<10^2$ and $\geq$100 CFU/g for the samples were determined to be 94.4% (N=221), 1.7% (N=4) and 3.8% (N=9). Moulds and yeasts counts greater than $10^4$ CFU/g were observed in 3 (1.3%) and 1.7% (N=4) cooked food samples respectively.

ACC $\geq 10^6$ CFU/g, total coliform and thermotolerant coliforms $\geq$104 CFU/g, *E. coli*$\geq$100 CFU/g, and moulds and yeasts counts greater than$10^4$ CFU/g were observed in 57 (23.8%), 28 (11.7%), 2 (0.9%), 5 (2.1%), 6 (2.5%) and 12 (5%) *cooked* meats and fish samples, respectively for catering premises; whereas ACC $\geq 10^6$ CFU/g, total coliform and thermotolerant coliforms $\geq 10^4$ CFU/g, *E. coli*$\geq$100 CFU/g, and moulds and yeasts counts greater than$10^4$ CFU/g were observed in 8 (32%), 3 (12%), 3 (12%), 4 (16%), 3 (12%) and 2 (8%) *cooked* poultry meats and fish samples, respectively for retail premises (restaurants).

Rho values of yeast, ACC and *E. coli* to total coliforms were 0.335, 0.552 and 0.331; mould and *E. coli* to thermotolerant coliforms were 0.388 and 0.632; ACC and yeast *to E. coli* were 0.277 and 0.169 respectively, and ACC to yeast was 0.251 (Table **2**). P-values for the indicators using Kruskal-Wallis test for the cooked samples by sample type, regions, premises, and *berbere* spice added vs not added, date and packed vs non-packaged have been given in Table **3**.

*Cooked* poultry meats of 101 samples, with ACC in the ranges of $<10^5$, $10^5$ - $< 10^6$ and $\geq 10^6$ CFU/g were determined to be 87.1% (N=88), 6.9% (N=7) and 5.9% (N=6) respectively. Total and thermotolerant coliforms ranges, $<10^2$, $10^2$ - $<10^4$ and $\geq 10^4$ CFU/g for the samples were found to be 83.2% (N=84), 12.9% (N=13) and 4% (N=4); 95% (N=96), 4% (N=4%) and 1% (N=1) respectively. *E. coli* ranges, <20, 20 - $<10^2$ and $\geq$100CFU/g for the samples were recorded to be 98% (N=98), 1% (N=1) and 2% (N=2). Moulds and yeasts counts greater than $10^4$ CFU/g were observed in 2% (N=2) and 1% (N=1) cooked food samples respectively.

**Table 1. Microbial counts in cooked meats and fish samples in different regions of Ethiopia from January 2013 to December 2017.**

| Parameter | Microbial Count (cfu/g) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **<1** | **19-Jan** | **20-99** | **102-103** | **104** | **105** | **106** | **>106** |
| Mould | 208 | 7 | 6 | 35 | 6 | 0 | 2 | 1 |
| Yeast | 216 | 1 | 9 | 25 | 9 | 5 | 0 | 0 |
| ACC | 66 | 1 | 25 | 62 | 46 | 33 | 26 | 6 |
| TC | 170 | 1 | 18 | 45 | 15 | 12 | 3 | 1 |
| TT | 232 | 3 | 6 | 19 | 2 | 2 | 0 | 1 |
| E. coli | 251 | 1 | 4 | 7 | 0 | 1 | 0 | 1 |

ACC– Aerobic Colony Count, TC–*total coliforms,* TT–thermotolerant coliforms.

**Table 2. Rho values of ACC, fungi, coliforms and *E. coli* in meats and fish samples between January 2013 to December 2017.**

| Parameters | Mould | Yeast | ACC | TC | TT | *E. coli* |
|---|---|---|---|---|---|---|
| Mould | 1 | - | - | - | - | - |
| Yeast | -0.075 | 1 | - | - | - | - |
| ACC | -0.035 | 0.251 | 1 | - | - | - |
| TC | 0.019 | 0.335 | 0.552 | 1 | - | - |
| TT | 0.388 | 0.001 | 0 | 0 | 1 | - |
| *E. coli* | 0.008 | 0.169 | 0.277 | 0.331 | 0.63 | 1 |

ACC– Aerobic Colony Count, TC–*total coliforms, TT*–thermotolerant coliforms.

**Table 3. P values for, fungi, ACC, coliforms and *E. coli* in meats and fish samples in Ethiopia by sample type, regions, catering, Pepper added *vs* not added, date and packed *vs* non-packaged between January 2013 to December 2017.**

| Parameters | Mould | Yeast | ACC | TC | TT | *E. coli* |
|---|---|---|---|---|---|---|
| Packaged vs non-packaged | 0.793 | 0.084 | 0.875 | 0.823 | 0.006 | 0.001 |
| Pepper added vs not added | 0.745 | 0.026 | 0.001 | 0.003 | 0.086 | 0.163 |
| premises | 0.31 | 0.471 | 0.543 | 0.179 | 0.432 | 0.009 |
| Sample type | 0.256 | 0.832 | 0.034 | 0.004 | 0. 152 | 0.213 |
| Regions | 0.017 | 0.614 | 0.004 | 0.034 | 0.025 | 0.001 |
| Year | 0.543 | 0.005 | 0.121 | 0.01 | 0.055 | 0.242 |

ACC– Aerobic Colony Count, TC–*total coliforms, TT*–thermotolerant coliforms.

*Cooked sliced* beef and mutton meats samples, with ACC in the ranges of $<10^5$, $10^5$ - $<10^6$ and $\geq 10^6$ CFU/g were found to be 63.5% (N=61), 167% (N=16) and 19.8% (N=19) respectively. Total and thermotolerant coliforms ranges, $<10^2$, $10^2$ - $<10^4$ and $\geq 10^4$ CFU/g for the samples were found to be 66.7% (N=64), 16.7% (N=16) and 16.7% (N=16); 89.6% (N=86), 8.4% (N=8%) and 2.1% (N=2) respectively. *E. coli* ranges, <20, 20 - $<10^2$ and ≥100CFU/g for the samples were determined to be 91.7% (N=88), 2.1% (N=2) and 6.3% (N=6). Moulds and yeasts greater than $10^4$ CFU/g were counted in 1% (N=1) and 3.1% (N=3) cooked food samples, respectively.

*Cooked* fish samples, with ACC in the ranges of $<10^5$, $10^5$ - $<10^6$ and $\geq 10^6$ CFU/g were tested to be 75% (N=51), 14.7% (N=10) and 10.3% (N=7) respectively. Total and thermotolerant coliforms ranges, $<10^2$, $10^2$ - $<10^4$ and $\geq 10^4$ CFU/g for the samples were found to be 60.3% (N=41), 23.5% (N=16) and 16.2% (N=11); 87.8% (N=86), 10.3% (N=8%) and 2.9% (N=2) respectively. *E. coli* ranges, <20, 20 - $<10^2$ and ≥100 CFU/g for the samples were determined to be 97.1% (N=88), 1.5% (N=1) and 1.5% (N=1). Moulds and yeasts counts greater than $10^4$ CFU/g were noticed in 0% and 1.5% (N=1) cooked food samples, respectively.

Poultry meats with *berbere* spice added had no ACC $\geq 10^6$ CFU/g, total and thermotolerant coliforms $\geq 10^4$ CFU/g and *E. coli*≥100 CFU/g in any of the samples, except moulds and yeasts counts greater than $10^4$ CFU/g in 2 (11.1%) and 1 (5.6%) samples, respectively. For the beef and mutton meats samples with *berbere* spice added, ACC $\geq 10^6$ CFU/g and moulds greater than $10^4$ CFU/g were observed each in 1 (8.3%) sample; but no total thermotolerant coliforms $\geq 10^4$ CFU/g, *E. coli*≥100CFU/g and yeasts counts greater than $10^4$ CFU/g in any of the samples.

Poultry samples with no spice added, with ACC $\geq 10^6$ CFU/g, total and thermotolerant coliforms $\geq 10^4$ CFU/g, *E. coli*≥100 CFU/g, moulds and yeasts counts greater than $10^4$ CFU/g were enumerated in 6 (7.2%), 1 (1.2%), 2 (2.4%), 2 (2.4. %) and 1 (1.2%) samples, respectively. For the beef and mutton meats samples with *berbere* spice not added, these microbial ranges were observed in 18 (21.4%), 16 (19%), 2 (2.4%), 0, 1 (1.2%) and 2 (2.4%) samples, respectively.

## 4. DISCUSSION

A microbiological investigation of ready-to-eat meats and fish was carried out to signify the quality and safety of the products. The finding of the bacteriological examinations of the samples was compared with international guidelines of Public Health Laboratory Service [23]. According to this guideline, the limits for aerobic colony count incubated for 48 hours at 30°C for satisfactory, acceptable and unsatisfactory categories which are $<10^5$, $10^5$ - $<10^6$ and $\geq 10^6$ CFU/g, respectively. In the present study, ACC for cooked ready-to-eat meats and fish were found to fall in the satisfactory, acceptable and unsatisfactory categories in 75.5% (N=200), 12.4% (N=33) and 12.1% (N=32) of the overall samples respectively. The unsatisfactory level of ACC can indicate food quality issues or poor temperature control [24].

The satisfactory, acceptable and unsatisfactory ranges for total and thermotolerant coliforms, $<10^2$,$10^2$ - $<10^4$ and $\geq 10^4$ CFU/g for the total samples were 71.3% (N=189), 17% (N=45) and 11.7% (N=31); 90.9% (N=241), 19% (N=7.2%) and 1.9% (N=5) respectively. The presence of coliforms in high numbers designates contamination and low microbial quality. This is may be due to contaminated raw material, cross-contamination during preparation or poor storage condition [25] poor quality of water for preparation, improper washing of utensils and post-process contamination caused by food handlers [26, 27].

*E. coli* satisfactory, acceptable and unsatisfactory ranges,

<20, 20 - <$10^2$ and ≥100CFU/g for the overall samples were 96.2% (N=252), 1.5% (N=4) and 3.4% (N=9) respectively. *Escherichia coli* is a common indicator and its detection in food generally indicates contamination of direct and indirect fecal matters [28] and the possibility enteric pathogens contamination [29]. *This organism* is not detected in cooked meat *products* from Tehran [30], Indies [31] and Zimbabwe [32].

The unsatisfactory microbial quality of cooked sliced beef and mutton meats samples in the current study as ACC (19.8%) was lower than the unsatisfactory microbial quality of cooked sliced meat samples tested in the UK [33] (26%). ACC, total coliforms, thermotolerant coliforms and *E. coli* have been found within acceptable levels in cooked beef, but *E. coli* in100% chicken samples was found in Zimbabwe [32]. In the present study, the presence of these indicators in 12.1%, 11.7%, 1.9% and 3.4% respectively in the total samples indicates poor handling and hygienic practices and possible danger [34].

The satisfactory, acceptable and unsatisfactory categories for *S. aureus* are <20, 20 - <100, 100 - <104 and ≥104 CFU/g. However, no detection of the pathogens in the examined samples in this study is suggestive of low human contact [35]. The absence of *S. aureus* in the tested cooked poultry meats, beef and mutton meats and fish samples was similar to the studies done on meats and fish in Nigeria [36] and New Zealand [37]. However, this organism is detected in researches conducted on meat products in Nigeria [38], Tehran [39] and Indies [31].

In the current study, meats and fish contained moulds and yeasts counts above Brazilian guideline acceptable limits above$10^4$ CFU/g in1.2% and 1.9% of the samples, respectively [40]. In contrast to these unsatisfactory levels of moulds and yeasts counts in the total cooked food samples in this investigation, in New Zealand [37] and Ethiopia, all moulds and yeasts have been found within the acceptable level in cooked meats [41]. These fungi reach the food articles from contaminated equipment, raw materials, air or by-cross contamination with man [42] and may cause infections or allergic reactions [43]. The existence of fungi in the samples could be due to poor packaging, storage, and poor perseveration of the food [38]. These microbes might affect the taste and quality of various foods and cause spoilage. Moulds can be suggestive of aging and they are responsible for the production of toxins that may affect human health [44].

The absence of Salmonella and Shigella spp. in RTE meats and fish in this study signifies adequate cooking or preventing cross contamination [44]. The non-detection of these pathogenic microorganisms in any of 25g cooked food samples tested was in line with the study done on cooked meat by Soriano 2000 [30], but in studies on cooked chicken, fish and beef and mutton meats products in Nigeria [37] and Srilanka [45]. The absence of unacceptable or potentially hazardous levels of microbial enumerations in the cooked poultry meats, beef and mutton meats and fish sample categories was in line with the findings in Slovakia [46].

The unsatisfactory levels for ACC, thermotolerant coliforms, *E. coli*, *moulds* and yeasts in unpackaged cooked poultry meats, beef and mutton meats and fish samples were 1.7 times, 2.6 times, 28.6 times, 1.3 times, and 5.4 times more than the unsatisfactory levels for packaged food samples. This might be as a result of environmental contamination or poor handling of unpackaged samples. There was a significant difference in thermotolerant coliforms (P value=0.006) and *E. coli* (P value=0.001) *levels* for packaged and unpackaged food samples.

The unsatisfactory levels for ACC, total coliforms, thermotolerant coliforms, *E. coli* and *moulds* and yeasts in cooked fish, beef and mutton meats and poultry meats with *berbere* spice not added were 4.4 times, 13.2 times, 14.7 times, 3.8 times and 1.3 times more than the unsatisfactory levels for samples with *berbere* spice added respectively. This may indicate the effectiveness of antimicrobial function of *berbere* spice. Statistically, there was a significant difference in yeast (P value=0.026), ACC (P-value=0.001) and total coliforms (P value=0.003) *levels* for samples with *berbere* spice added and not added.

The unsatisfactory levels for ACC, total coliforms, thermotolerant coliforms, *E. coli* and *moulds* in cooked unpackaged poultry meats, beef and mutton meats and fish with *berbere* spice not added were 19.2 times, 10.6 times, 4.3 times, 17 times and 2.1 times more than the unsatisfactory levels for packaged samples with *berbere* spice added respectively.

The unsatisfactory microbial quality of cooked poultry meats, beef and mutton meats and fish collected from retail premises (restaurants) for ACC, total coliforms, thermotolerant coliforms, *E. coli, moulds* and yeasts were 1.3 times, 1.0 times, 13.3 times, 7.6 times, 4.8 times and 1.6 times more than the unsatisfactory levels for the samples collected from catering premises, respectively. However, there was no statistically significant difference between the microbial quality of cooked poultry meats, beef and mutton meats and fish samples from restaurants compared with those from catering premises except for *E. coli* (P value= 0.009).

The non-parametric Spearman Correlation test showed statistically significant positive correlations between yeast and hygienic bacterial indicators (ACC and total coliforms) and between mould and thermotolerant coliforms. The finding of the current study generally revealed that among the categories of three ready to eat foods examined, beef and mutton meats, fish and poultry, respectively, had the highest and lowest microbial contamination. The Kruskal Wallis test showed that sample types (cooked fish, beef and mutton meats and poultry meats) differ significantly from each other for the contamination by ACC (p value= 0.034) and total coliforms (p value= 0.004). All the bacterial indicators and yeasts differed statistically by regions; yeasts and total coliforms differed by years. (P values < 0.05).

Out of 265 cooked fish, beef and mutton meats and poultry meats, 208 (78.5%) samples had satisfactory or acceptable microbiological quality, but the rest of 57 (21.5%) samples contained one or more bacterial indicators or fungi with unsatisfactory counts.

## CONCLUSION

About 21% of the poultry, beef and mutton and fish samples had unsatisfactory microbial quality because of bacterial indicators or fungi based on international guidelines. However, *Salmonella*, *Shigella* spp. and *S. aureus* were not detected in the samples tested. To avoid public health risks, meats and fish should be processed under hygienic conditions and adding *berbere* spice to food and packaging enhances the quality of ready to eat articles. Moreover, regular assessment of the products using quality and safety parameters is important.

## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| **ACC** | = | Aerobic Colony Count |
| **CFU/g** | = | colony-forming units per gram |
| ***E. coli*** | = | *Escherichia coli* |
| **NMKL** | = | Nordic Committee on Food Analysis |
| **SNNPR** | = | Southern Nations, Nationalities, and Peoples' Region |
| ***S. aureus*** | = | *Staphylococcus aureus* |

## AUTHORS' CONTRIBUTIONS

Tesfaye Legesse: the concept, design, analysis, interpretation of data and writing.

Firehiwot Abera- analysis, revision and approval of the final version

Samson Girma- design, revision and approval of the final version

Waktole Gobena- drafting, revision and approval of the final version

Tigist Yohannis- revision and approval of the final version

Tatek Kasim- revision and approval of the final version

Kaleab Sebsibe- revision and approval of the final version

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

## HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

## AVAILABILITY OF DATA AND MATERIAL

The authors confirm that the data supporting the findings of this research are available within the article.

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None.

## CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

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