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Research Article

Assessment of Microbiological Safety and Quality of Minced Meat and Meat Contact Surfaces in Selected Butcher Shops of Addis Ababa, Ethiopia

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Food-borne pathogens are one of the leading causes of illness and death particularly in developing countries. This study was aimed at analyzing the hygiene indicator microorganisms and pathogens of minced meat and contact surface materials in butcher shops in Addis Ababa, Ethiopia. Additionally, a checklist was applied to evaluate the hygiene condition of the establishments, and a questionnaire/checklist was used to assess food safety knowledge of the food handlers. This study has indicated that the mean microbial counts (total aerobic mesophilic, staphylococci, *Enterobacteriaceae*, total coliforms, fecal coliforms, aerobic spores and yeasts/molds) of the minced meat and contact surface materials in butcher shops ranged between 2.35 and 6.50 log·cfu/g and between 1.80 and 6.30 log·cfu/cm^2, respectively. The mean microbial counts of minced meat samples taken in the morning and afternoon showed statistically significant differences ($p < 0.05$). The prevalence of *E. coli*, *Salmonella*, and *S. aureus* in minced meat and contact surface samples was exhibited as 43.75 and 29.17%, 6.25 and 4.17%, and 37.50 and 37.50% in that order. The study has indicated that minced meat samples and contact surface materials had higher microbial load with poor personal and work area sanitation. Low knowledge of food handlers in the butcher shops and broken cold chain have also been found as major contributing factors for the contamination of beef.

1. Introduction

Meat is the major source of protein and valuable qualities of vitamins for most people in many parts of the world and is essential for the growth, repair, and maintenance of body cells and necessary for our everyday activities. However, fresh meat is highly prone to contamination regardless of its nutritional values. Ingestion of infected food may cause mild to severe illness with hospitalization or even death. Recent data from either developing or developed countries indicated that at least 10% of the population may experience food-borne diseases [1]. The situation is more serious in developing countries, with obvious economic consequences [2]. In 2002, the Centers for Disease Control (CDC) in the United States reported 76,000 cases of food-borne illness, the majority being of bacterial origin [3]. Haeghebaert et al. [4] have indicated that out of 559 cases, 64% of food-borne diseases reported in France were due to salmonellosis. In Ethiopia, like other developing countries, it is difficult to evaluate the burden of food-borne pathogens because of the limited scope of studies and lack of coordinated epidemiological surveillance systems [5]. In addition, underreporting of cases and the presence of other diseases are considered to be of high priority and may have overshadowed the problem of food-borne pathogens [6].

In Ethiopia, the demand for meat products is dramatically increasing, and the consumption of raw meat becomes a symbol of status [7]. The same authors further noted that around 30% of the national meat consumption share is in Addis Ababa. However, the full value chain of meat supply

from abattoirs, distribution, butchery shops to final consumers are not properly handled to ensure the microbial quality, safety, soundness, wholesomeness, and hygiene. In addition, there is no adequate information regarding the assessment of food safety practice, food-borne diseases, and microbial load on meat contact surfaces of meat-processing materials in butchery shops on a regular basis. These factors could hinder government and other stockholders to accurately apply measures on the impact of food contamination problems to public health. Generally, microbial contamination in food-processing plants can play a basic role in food quality and safety [8]. The consumers have also limited information on quality and safety of the meat consumed regularly; moreover, raw meat is a highly perishable product [9]. Therefore, this study was focused on determining the hygienic status and microbial load and identifying food-borne pathogens from minced meat and contact surfaces of meat-processing materials in the butcher shops in Addis Ababa, Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted in Gullele Subcity, Addis Ababa. Gullele Subcity covers 30.18 km^2. It is one of the ten subcities in Addis Ababa, According to the Central Statistics Agency [10], the population size of the Gullele Subcity was 284,865 with the population density of 9,438/m^2.

2.2. Study Design. A cross-sectional study was carried out to collect data from multiple cases during the study period of two months. Systematic random sampling technique was employed to assess the beef quality and safety and the source of contamination of the meat-processing materials in the butcher shops. For this study, samples of beef from butcher shops were collected using sterile containers in the form of minced meat for microbial analysis of beef with the aim of enumerating viable microbial cells and identifying pathogenic bacteria.

A checklist/questionnaire was used to assess risk factors concerning standard facilities, materials handling, and current status of food hygiene and sanitation practices in butcher shops. Hygiene and sanitation were determined by the use of structured interview and through direct observations of the hygienic status and practices of butcher shops' workers.

2.3. Questionnaire and Interview Survey. A checklist was prepared to assess the (i) sociodemographic characteristics of the study subjects, (ii) knowledge of workers in butcher shops regarding the hygienic practices during processing of meat, (iii) availability of proper training on hygienic practices, and (iv) facilities of the premises. The respondents (two workers from each butchery shop) were given with the checklist/questionnaire to respond accordingly. Educational status, exposure and frequency of training, hair cover, jewellery, money handling practice, frequency of hand washing, and effectiveness of training were included in the questionnaire. Before this survey, a pilot test was conducted in order to decide how to manage the questionnaire.

2.4. Sample Collection and Preparation. In this study, a total of 40 samples out of which 16 were minced beef meat and the rest 24 were surface swab samples collected from 8 butcher shops in Addis Ababa. Beef meat samples (500 g from each cut and minced at the butchery) were also collected in sterile plastic bags from 8 randomly selected butcher shops in Addis Ababa, which were sourced from the Addis Ababa Abattoirs Enterprise (AAAE.) The samples were placed in icebox (4°C) and transported to the Center for Food Science and Nutrition Laboratory, Addis Ababa University (AAU), for immediate analysis. The minced meat samples were collected in the morning (8 : 00–9 : 00 a.m.) and late in the afternoon (5 : 00–6 : 00 p.m.). Therefore, 16 (8×2) meat samples (eight samples in the morning and the other eight in the afternoon) from butcher shops were considered for the study. Furthermore, 24 (8×3) swab samples were randomly collected aseptically from butcher shops' knives, cutting tables, and weighing balances in the afternoon. An area of 1 cm^2 was used for swabbing with sterile swabs soaked in 10 ml of 0.1% saline solution. The swab samples were kept in sterile broth in icebox cooler and taken to the laboratory for further study as indicated by Gurmu and Gebretinsae [10] and Obeng et al. [11].

2.5. Enumerations of Major Groups of Microorganisms. For microbial enumeration, 25 g of minced meat samples were transferred aseptically into a sterile stomacher bag containing 225 ml of sterile distilled water and homogenized using the Stomacher lab blender (Depofen, France). Swab samples (10 ml of 0.1% saline solution) were vortexed to ensure mixing of the sample. Homogenized samples were serially diluted to prepare tenfold appropriate dilutions. From appropriate dilution, 0.1 ml aliquot was spread-plated on respective media for detection and counting of different groups of organisms [12].

Total aerobic mesophiles (TAM), total coliforms (TC) and fecal coliforms (FC), members of *Enterobacteriaceae* (EB), total staphylococci (TS), aerobic spore (AS) formers, and yeasts/molds (YM) were counted on appropriate media. For TAM count, plate count agar (PCA) plates were incubated at 32°C for 48–72 h. Inoculated violet red bile agar (SRL) plates for TC and FC counts were incubated at 32°C and 44.5 C for 18–24 h in that order.

MacConkey agar (SRL) supplemented with glucose was used to count members of *Enterobacteriaceae* after incubating plates at 35°C for 24 h [12]. Mannitol salt agar (MSA) was employed to count staphylococci. Purified colonies were tested for coagulase positivity as a confirmatory test for staphylococci [12]. For counting aerobic spore formers on PCA, appropriate dilution factors were heated in a water bath for ten minutes that was adjusted at 80°C. Plates were incubated at 30°C for 36 to 72 h. Yeasts and molds were counted on potato dextrose agar supplemented with 0.1 g chloramphenicol. After incubating plates at 25°C for 3–5 days, typical yeasts/molds colonies were counted [13].

2.6. Characterization of Dominant Microflora. After counting TAM on PCA plates, about 10–20 colonies were picked randomly from countable plates and inoculated into tubes containing about 5 ml Nutrient Broth (HIMEDIA). Cultures were incubated at 30°C overnight. The cultures were purified by repeated plating and were characterized to the genus level and/or various bacterial groups using morphological typing and biochemical tests [14]. Wet mounting, Gram-staining, and spore-staining techniques were conducted following standard procedures in order to observe bacterial cell shapes (spherical, rod, spiral, etc.) and arrangements (single, pair, chain, clusters, tetrads, etc.). For biochemical analysis, oxidation-fermentation (O/F), cytochrome oxidase, and catalase tests were conducted following the methods in the study of Bergey et al. [15].

2.7. Detection of Pathogenic Microorganisms. Detection of *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella* species from collected food and surface swab samples was done following a procedure given in the American Public Health Association [13]. For the detection of *Escherichia coli,* suspected isolates from the FC-counting plates were tested for production of gas in *Escherichia coli* broth (CONDA) following the protocol given in NMKL [16]. Further confirmation of gas-producing isolates was done by carrying out indole, MRVP, citrate, and triple sugar iron tests [15]. The detection of *Staphylococcus aureus* was done on the golden-yellow colonies from MSA plates checking for catalase and coagulase positivity [13].

Detection of *Salmonella* spp. was done by adding 1 ml of original suspension from minced meat and surface swabs into each of 10 ml tetrathionate broth (supplement with iodine) (SRL) and 10 ml selenite cystine broth (HIMEDIA). The inoculated tubes were incubated at 44°C for 48 h and 37°C for 24 h, respectively. A loop full of enriched cultures was streaked separately onto xylose lysine deoxycholate (XLD) agar (OXOID) and *Salmonella Shigella* (SS) agar (HIMEDIA) plates. Incubation of inoculated plates and identification of presumptive *Salmonella* colonies were conducted as shown in NMKL [16, 17]. Further biochemical tests were done by employing different identification methods using triple sugar iron agar [16, 17], lysine iron agar [16, 17], Simmons citrate agar [16, 17], urease test [16, 17], and serological test [17, 18].

2.8. Data Analysis. The quantitative data were entered into Microsoft Excel spreadsheet and were analyzed using Statistical Package for Social Sciences (SPSS) version 20 (one-way ANOVA). For means separation, LSD test was used at 5% level of significance.

3. Results

3.1. Observation of Butcher Shops. The survey results showed that 14/16 (87.5%) of the meat handlers were males and out of which 12/14 (85%) of them were found only educated to elementary level (Table 1). Out of the meat handlers, 10/16 (62.5%) of them took training on sanitation and food handling. However, only 8/16 (50%) of them had renewed their health certificates. Results of sanitary survey has indicated that 6/16 (37.5%), 4/16 (25%), and 6/10 (37.5%) of the meat handlers wore clean working coats, put on hair covers, and cut their nails short and kept it clean in that order. Moreover, 2/8 (25%) of the butcher shops have cashiers. It was observed that the meat products were not separated from offals (internal organs) and were displayed for sale uncovered for more than 5 hours. It was also observed that only 1/8 (12.5%) of the shops had refrigerator.

Our results showed also that 4/16 (25%) of the workers considered in the study were observed having visible skin rashes, boils, and cuts or wounds (Table 1). Observation of the general sanitary condition indicated that only 2/8 (25%) of the butcher shops were found in a good sanitary status and the rest were in poor state (6/8 (75%)). Regarding the sanitation and location of toilets, it was observed that only 2/8 (25%) of the shops have clean and washrooms located in reasonable distances from meat display sites.

3.2. Microbiological Analysis

3.2.1. Microbial Quality of Fresh Minced Meat Samples. The mean counts of morning and afternoon minced meat samples of total aerobic mesophilic (TAM), total staphylococci (TS), and aerobic spore formers (AS) were 6.50 and 6.85 log·cfu/g, 4.57 and 5.78 log·cfu/g, and 2.35 and 2.42 log·cfu/g, respectively (Table 2). The mean morning and afternoon counts of *Enterobacteriaceae* (EB), total coliforms (TC), fecal coliforms (FC), and yeast/molds (YM) were indicated as 6.31 and 6.77 log·cfu/g, 6.17 and 6.83 log·cfu/g, 5.53 and 6.11 log·cfu/g, and 5.59 and 6.04 log·cfu/g in that order. In this study, the TS, EB, FC, and YM counts of minced meat samples which were taken in the morning and afternoon were shown to have statistically significant differences ($p < 0.05$) (Table 2).

3.2.2. Microbial Quality of Contact Surface Materials in Butcher Shops. The mean TAM counts of knives, cutting tables, and weighing balances were shown as 6.31, 6.32, and 6.34 log·cfu/cm^2, respectively (Table 3). The mean TS count was recorded between 3.72 and 3.99 cfu/cm^2 for the materials. The average EB and TC counts of the contact surfaces were found ranging from 4.85 to 4.93 and from 5.34 to 5.70 log·cfu/cm^2 in that orders. The mean counts of FC were recorded as between 4.42 and 4.61 log·cfu/cm^2. The mean AS counts ranged from 1.96 to 3.27 log·cfu/cm^2, in which the maximum count was observed from balance. The mean YM counts were found ranging from 4.92 to 5.92 log·cfu/cm^2. Generally, there were no significant ($p > 0.05$) differences in all counts except for AS counts (Table 3).

3.2.3. Microbial Load of Samples from Different Categories. From a total of 40 samples, 27/40 (67.5%) samples collected showed TAM counts >10^6 (Table 4). The ST counts of 26/40 (65%) of samples were found to have counts

Table 1: Sex, educational status, and survey on knowledge of butchers on hygienic practices in Gullele Subcity.

Variable	Values	Frequency no. (%)	Variable	Values	Frequency no. (%)
Sex	Male	14 (87.5)	Paper money handling[3]	Separate cashier	1 (6.5)
	Female	2 (12.5)		Butcher	7 (43.75)
Educational status	Literate	6 (37.5)	Visible skin rash, boils, cuts or wounds	Yes	4 (25)
	1–6[1]	6 (37.5)		No	8 (50)
	7–10[2]	4 (25)		Difficult	4 (25)
Training	Yes	10 (65.5)	Health certificate	Certified	8 (50)
	No	6 (37.5)		Not	8 (50)
Clean overcoat	Yes	6 (37.5)	Hair cover	Yes	4 (25)
	No	10 (65.5)		No	12 (75)
Nail shortness & cleanliness	Yes	6 (37.5)	Refrigerator usage[3]	Yes	1 (6.5)
	No	10 (65.5)		No	7 (43.75)
General sanitation of shop[3]	Better	0 (0)	Location of toilets and possibilities of contamination[3]	Yes	3 (18.75)
	Good	2 (12.5)		No	2 (12.5)
	Poor	6 (37.5)		Difficult	3 (18.75)

*Training on personal hygiene and environmental sanitation. [1]Elementary school completed. [2]Secondary school completed. [3]No. of shops.

Table 2: Comparison of microbial counts (log·cfu/g) of minced meat samples collected from butcher shops.

Microbial types	Collection period					
	Morning (values in log·cfu/g)			Afternoon (values in log·cfu/g)		
	Mean (+SD)	Min	Max	Mean (+SD)	Min	Max
Total aerobic mesophilic	6.50 ± 0.82^{a}	5.000	7.12	6.85 ± 0.83^{a}	5.30	7.44
Total staphylococci	4.57 ± 0.87^{b}	3.000	5.78	5.77 ± 0.62^{a}	4.75	6.28
Enterobacteriaceae	6.31 ± 0.86^{a}	4.87	6.97	6.77 ± 0.69^{a}	5.17	7.48
Total coliforms	6.17 ± 0.69^{a}	5.00	6.94	6.84 ± 0.65^{a}	5.30	7.28
Fecal coliforms	5.53 ± 0.79^{b}	4.76	6.86	6.11 ± 0.83a	5.35	7.32
Aerobic spores	2.35 ± 1.601^{a}	BDL	3.81	2.42 ± 1.66^{a}	BDL	4.00
Yeast and molds	5.59 ± 1.15^{b}	4.32	6.96	6.04 ± 1.18^{a}	4.81	7.31

SD: standard deviation; Min: minimum; Max: maximum. Data are means ± SD from two replications, and values followed by different letters within row indicate significant differences ($p < 0.05$).

Table 3: Microbial load (log·cfu/cm^2) of samples from contact surface of eight butcher shops.

Microbial types	Contact surfaces counts (log·cfu/cm^2)								
	Knife ($n = 8$)			Cutting table ($n = 8$)			Balance ($n = 8$)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Total aerobic mesophilic	6.31^{a}	4.95	7.1	6.32^{a}	5.18	7.47	6.43^{a}	5.27	7.3
Total staphylococci	3.85^{a}	BDL*	4.95	3.99^{a}	3.00	5.13	3.72^{a}	BLD	5.9
Enterobacteriaceae	4.93^{a}	4.3	5.47	4.85^{a}	3.77	5.67	4.93^{a}	4.2	5.2
Total coliforms	5.51^{a}	4.39	6.87	5.34^{a}	4.40	6.9	5.70^{a}	4.4	5.9
Fecal coliforms	4.61^{a}	4.3	5.00	4.42^{a}	3.50	5.1	4.44^{a}	3	5.1
Aerobic spores	1.96^{ab}	BDL*	3.77	1.87^{bc}	BDL*	3.33	3.27^{a}	2	4.1
Yeast and molds	5.03^{a}	3.47	6.84	4.92^{a}	3.50	6.01	5.17^{a}	4.1	6.16

SD: standard deviation; Min: minimum; Max: maximum. Data are means ± SD from two replications, and values followed by different letters within row indicate significant differences ($p < 0.05$). *BDL: below detectable level.

<6 log·cfu/g. EB counts in 25/40 (62.5%), TC counts in 21/40 (52.5%), and FC counts in 35/40 (87.5%) of samples collected were found as 4 to <6 log·cfu/g. Moreover, the counts of EB and TC in 4/40 (10%) and FC in 2//40 (5%) samples collected were shown as >7 log·cfu/g. In this study, the counts of AS were exhibited as ranging from 2 to <6 log·cfu/g in samples of 30/40 (75%) collected. Accordingly, yeasts/mold counts were shown from 4 to <6 log·cfu/g in samples of 28/40 (70%) collected. Generally, the overall counts of TAM, ST, EB, TC, FC, and YM indicated the presence of heavy level of contaminations of both minced meat and contact surface materials considered in this study. On the basis of TAM count, 67.5% of the meat samples were classified as unsatisfactory (following European Standards (EC) [19] and Food and Safety and Standard Authority of India [20]). Regarding *Enterobacteriaceae* and fecal coliform counts, the meat samples were categorized as unsatisfactory (Table 4).

Table 4: Microbial load in log·cfu/g of the total samples with their range of microbial counts.

Microbial types	No. of samples (%) with their range of microbial counts in log·cfu/g					Total no. of each sample
	BDL	2–<4	4–<6	6-<7	>7	
Total aerobic mesophilic	0 (0)	0 (0)	13 (32)	11 (28)	16 (40)	40
Total staphylococci	2 (5)	8 (20)	26 (65)	4 (10)	0 (0)	40
Enterobacteriaceae	0 (0)	1 (3)	25 (63)	10 (25)	4 (10)	40
Total coliforms	0 (0)	0 (0)	21 (53)	15 (38)	4 (10)	40
Fecal coliforms	0 (0)	0 (0)	35 (88)	3 (8)	2 (5)	40
Aerobic spores	10 (25)	27 (68)	3 (8)	0 (0)	0 (0)	40
Yeast and molds	0 (0)	0 (0)	28 (70)	10 (25)	2 (5)	40

BDL: below detectable level; SD: standard deviation; Min: minimum; Max: maximum. Data are means ± SD from two replications, and values followed by different letters within row indicate significant differences ($p < 0.05$).

3.2.4. Dominant Microflora. A total of 105 bacterial isolates from aerobic mesophilic plates were recovered and characterized to various genera and bacterial groups from beef and contact surface materials from butcher shops (Figure 1). Accordingly, the aerobic mesophilic flora was dominated by *Enterobacteriaceae* (29.50%) followed by *Staphylococcus* spp (26.67%) and *Bacillus* spp (17.40%). These were followed by *Streptococcus* spp (7.62%), *Micrococcus* spp (6.67%), *Pseudomonas* spp (4.76), *Acinetobacter* spp (2.86%), and *Aeromonas* spp (2.86%).

3.2.5. Detection and Frequency Distribution of Pathogenic Microorganisms. In this study, from a total 40 samples, 14 (35%) of them were presumptively designated as positive for the presence of *E coli* (Table 5). Out of the total samples, the frequency of *E. coli* was higher for minced meat (7/16, 43.75%) compared to the contact surface samples (7/24, 29.17%). Only 2/40 (5%) samples were shown to be positive for presence of *Salmonella*. On the contrary, 6/16 (37.5%) samples from minced meat and similar percentage for contact surface material (9/24) samples were found positive for the presence of *S. aureus*.

4. Discussion

It was shown that one-third of the meat handlers did not complete elementary school unlike the investigation done in Uganda where 42/80 (57.5%) of meat handlers attained secondary level of education [21]. Even though more than half of the meat handlers in this study had taken training on food handling and personal hygiene, their practice towards good manufacturing practices was found to be poor. Similarly, Gurmu and Gebretinsae [10] have reported that only 58.4% (7/12) of the meat handlers in Mekelle, Ethiopia, had taken trainings related to personal hygiene and food handling. Moreover, Walker et al. [22] have reported that 55% of the food handlers surveyed had taken formal food hygiene training. On the contrary, the UK Audit Commission found a strong link between food-borne illness with poor hygienic practices and low level of trainings. Additionally, a correlation between management attitude towards training, levels of food hygiene knowledge, and standards of food-handling practice has been identified [22].

In this study, only less than half of the meat handlers wore clean working coats and a large number of them did not wear hair covers and their hands' nails were not clean (Table 1). This result is in agreement with that of Gurmu and Gebretinsae [10] who reported that 5/12 (41.70%) meat handlers did not wear overcoats and 7/12 (58.3%) of them did not put hair covers. On the contrary, Tafesse et al. [23] have reported none of the food handlers wore hair cover. Another study done in Kenya has shown that 70% and 82% of the butchery operators in Nairobi and Isiolo, respectively, did not wear protective clothing while selling meat [24]. In addition, the regulations of the Division of Food and Nutrition, WHO [25], stated that food handlers should wear clean and proper clothing and should wash their hands with soap and water after any activity that is likely to introduce hazards.

Results of this study have indicated that many of the butchers handled money (papers/coins) while serving meat. The same was noted by Gurmu and Gebretinsae [10], where 91.7% of the food handlers handled money frequently while serving food. Sharon et al. [24] in Kenya have shown that 90% and 87% of the butchery operators in Isiolo and Nairobi Counties, respectively, handled money while handling of meat.

The overall sanitation of the butcher shops considered in this study was found to be poor. The meat products were not separated from offals, and only one butcher shop had a refrigerator. In comparison with the current study, Sharon et al. [24] have reported that only 11% of the butchers had stored beef in refrigerators. Similarly, Nonga et al. [26] and Toyomaki [27] have reported that 85% of the butcher shops in Morogoro Municipality, Tanzania, and 76.7% of butchers in Arusha, Tanzania, did not have refrigerators, respectively. This poor sanitation creates conducive environment for cross contamination and poor cold chain management. In this study, most of the meat products were held on hangers or on tables for more than 5 hours. Comparative to this, a study conducted in India [28] has shown similar situation where fresh beef stored at room temperature for extended period of time. This practice may give sufficient time for microbial growth. In agreement with this, Muleta and Ashenafi [29] reported that microorganisms duplicate luxuriously, if ready-to-eat food is kept for 4 hours at temperatures of 15–45°C.

Minced meat samples yielded high mean total aerobic mesophilic (TAM) counts (>6 log·cfu/g) in the morning and even more in the afternoon. Comparative to this study, a study conducted in Northern Ghana [16] has reported that

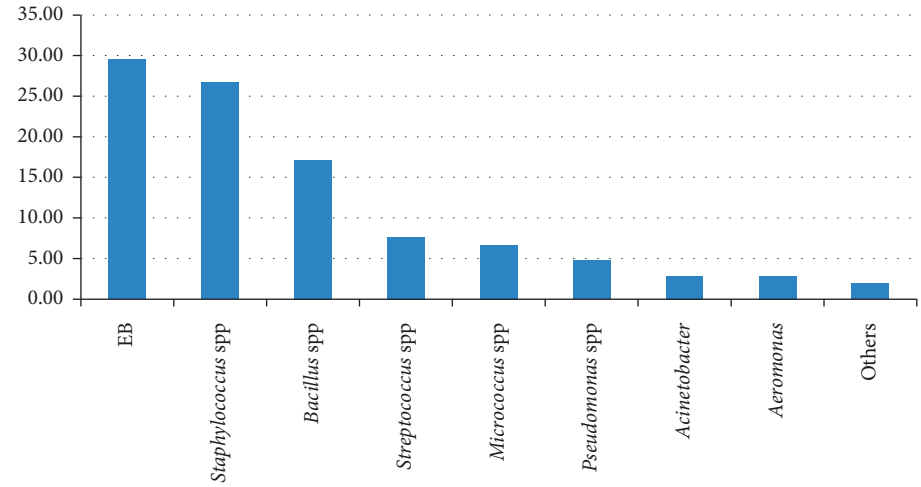

Figure 1: Frequency distribution of mesophilic bacteria in meats collected from and contact surface materials in butcher shops.

Table 5: Frequency distribution of suspected pathogenic bacteria of meat and contact surface samples.

Site	*E. coli*			*Salmonella*		*S. aureus*	
	No. of tested samples	Positive	Percentage	Positive	Percentage	Positive	Percentage
Contact surface	24	7	29.17	1	4.17	9	37.5
Minced meat	16	7	43.75	1	6.25	6	37.5
Total	**40**	**14**	**35**	**2**	**5**	**15**	**37.5**

there were 2 log microbial load differences between morning and afternoon meat samples. Similarly, greater than 6.80 log·cfu/g TAM counts of minced beef samples were reported by Kebede et al. [7].

In this study, mean total staphylococci counts of minced meat samples collected in the afternoon showed increment by 1.2 log·cfu/g from the morning samples (Table 2). An investigation done by Sharon et al. [24] showed higher staphylococcal load (ranging from 5.8–7.5 log·cfu/g). Similarly, Mezgebu and Mogessie [30] have reported heavy bioburden of staphylococci (6 cfu·log/g) from minced meat. The high counts of staphylococci could be associated with improper personal hygiene of untrained employees and cross contamination from skin and utensils [31].

Our result indicated that members of EB, TC, and FC counts of butcher meat samples were found higher in the afternoon than in the morning as reported by Tafesse et al. [23]. This higher count could be an indication to broken cold chain management practice and poor sanitation system. Since members of *Enterobacteriaceae* are safety indicators, their high counts may be associated with the possible presence of potential pathogens [32]. On the basis of our results, all the samples from butcher shops were classified as unsatisfactory. The high fecal coliforms count could be due to cross contamination from the gut of the animals and immediate fecal contamination [33] that potentially implicate the presence of enteric pathogens. However, studies by Kammenou et al. [34] and Çetin et al. [35] have reported lower counts of EB and coliforms from minced meat samples. In the present study, mean aerobic spore and yeast/mold counts were low compared to that mentioned in the study of Mezgebu and Mogessie [30] who reported higher counts of yeasts/molds. On the contrary, Bekele et al. [36] have also reported lower counts of YM and AS formers from minced meat.

Mean TAM counts (6.56 and 6.78 log·cfu/cm^2 from table and knife, respectively) of this study were found to be slightly lower than those reported from northern Ethiopia [37]. However, lower mean TAM counts of knives and cutting tables (6.01 and 6.03 log·cfu/cm^2, respectively) were reported from Jigjiga, Ethiopia [38]. Enumeration of higher TAM counts from the contact surfaces indicated insufficient cleaning practices in the butcher shops [34]. The mean TS counts (3.99 and 3.75 log·cfu/cm^2 in that order) of meat-cutting tables and weighing balances of the present study were higher than a study conducted elsewhere [39] which reported 3 log·cfu/cm^2. The difference could be attributed to the inadequate sanitary and handling practices exercised in the butcher shops at the study area.

Mean EB counts (4.93 and 4.83 log·cfu/cm^2 from knives and cutting boards, respectively) of this study were found comparable to a study conducted by Ayalew et al. [38]. In this study, the mean TC counts of knives and working tables were shown as 5.51 and 5.34 log·cfu/cm^2 which were higher than those mentioned in another study in the UK [39]. Report of FC counts from cutting boards and knives of a study from Jigjiga, Ethiopia [38], indicated 5.80 and 5.83 log·cfu/cm^2. The presence of poor hygienic practices and cross contaminations in butchery shops may increase the counts of fecal coliforms [33]. The mean yeast/mold count of contact surfaces in our study was close to 5 log·cfu/cm^2, which was higher than that mentioned in a comparative

study done by Ayalew et al. [38]. These high microbial loads (TAM, TS, TC, EB, FC, and YM counts) from the contact surfaces, in all counts, may indicate the potential presence of pathogenic microbes and may contribute to the contamination of meat products [40].

The current study indicated that *Enterobacteriaceae, Staphylococcus* spp, and *Bacillus* spp were dominating the microflora of meat and contact surface samples. This in turn indicates that the microbial quality and safety was highly compromised, and the consumption of these products may lead to infections [33]. Similarly, Dabessa and Bacha [41] reported that microflora of meat samples collected from households in Jimma, Ethiopia, was dominated by *Bacillus* spp, *Staphylococcus* spp, and members of *Enterobacteriaceae.* A similar study from Calabar, Cross River State-Nigeria [42] demonstrated that the microflora of the beef samples was dominated by *Enterobacteriaceae* (28.56%), *Staphylococcus* (21.4%), *Bacillus* spp (21.4%), and *Streptococcus* (14.29). Moreover, Tassew et al. [43] have reported that the microflora of the beef samples was dominated by *Enterobacteriaceae* (85%) and followed by *Staphylococcus* spp (12.2%).

The prevalence of *E. coli* in this study was found as 43.75% and 29.17% in minced meat and contact surfaces of some materials in butcher shops, respectively. Similarly, a study done by Kebede et al. [7] and Gurmu and Gebretinsae [10] showed the prevalence of *E. coli* in 30% and 32% of meat and contacts surface samples collected from butcher shops. These results clearly revealed the exercise of unhygienic meat-handling practices in butchers' shops. Even though the presence of *E. coli* in foods are not always alarming due to the fact that most strains are harmless and opportunistic in nature [31], but the harmful strains (*E. coli* O157) recovered from meat samples of retailers can pose gastroenteritis by producing shiga toxin [36].

In the present study, a significant number of meat samples collected from butcher shops showed the presence of presumptive *Salmonella* spp with a prevalence rate of 4.17% as noted by Gurmu and Gebretinsae [10]. The detection of *Salmonella* in any sample could be due to poor hygiene and sanitary practices through all value chains of the meat supply and indicated the potential risk associated with the consumption of these foods [44]. The same authors further remarked that contamination of food with *Salmonella* spp could enormously exhibit high public health risk especially where consumption of raw meat is quite common with no and/or rudimentary surveillance system.

Over 37% of meat samples of this study showed the presence of coagulase-positive *S. aureus.* A similar study done by Kedir [45] has showed that 31% of meat samples carried coagulase-positive *S. aureus*. A study done by Pesavento et al. [46] has shown 29.4% prevalence of *S. aureus* in meat samples. Cross contamination of meat samples by coagulase-positive *S. aureus* has been demonstrated by several investigators [29, 45], indicating the health risks of consuming raw minced meat handled under unhygienic conditions. Gurmu and Gebretinsae [10] have reported higher prevalence rate of *S. aureus* from the contact surface materials in butcher shops than the present study. Generally, high contamination of food with *S. aureus* has been related to improper personal hygiene practices of employees during handling and processing of meat products [31].

5. Conclusion

Low level awareness of hygienic practices, frequent handling of paper currency, broken cold chain, and poor sanitation of the butcher shops are among the predominant factors those led to the contamination of beef meat and seriously compromise the quality of the meat products. Microbial load of minced meat was found to be more in the samples collected in the afternoon than those collected in the morning. This high microbial load may indicate the presence of pathogenic microbes and this may in turn contribute to the risk associated with the consumption of the products. Poor microbial quality of the processing environment and the product itself can cause serious health risks and call for proper intervention efforts.

Abbreviations

AAAE: Addis Ababa Abattoirs Enterprise
AAU: Addis Ababa University
AS: Aerobic spores
BDL: Below detectable level
EB: *Enterobacteriaceae*
FC: Fecal coliforms
PCA: Plate count agar
SD: Standard deviation
SPSS: Statistical Package for Social Sciences
SRL: Sisco Research Laboratories
SS: *Salmonella Shigella* agar
ST: Staphylococci
TAM: Total aerobic mesophilic
TC: Total coliforms
XLD: Xylose lysine deoxycholate agar
YM: Yeast and molds.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All the authors contributed to the conceptualization of the project and to the initial grant application. KZ prepared the first draft of the manuscript, and it was reviewed by all authors.

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