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Research Article

Impact of Processing Methods on the Bacteriological Quality of Poultry Portioning Operations in Khartoum State, Sudan

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Abstract

This study was carried out to investigate the bacterial load in portioned poultry meat operations in Khartoum State from February 2018 to August 2020. Twelve (36.4%) operations were selected out of 33 of poultry portioning meat of which 6 were chosen randomly from the traditional and 6 from the modern sectors to cover the three localities of Khartoum State. Swab sample method was used for bacterial count. A total of 288 swab samples were randomly collected. Sterile swab was swabbed in the breast and leg skin of chicken at different process steps. The study revealed no significant differences between traditional and modern sectors in terms of mean of total count $\log_{10}$ (cfu/g) of water samples, hand samples before and after portioning, work surface samples before and after portioning, while the mean of total count $\log_{10}$ (cfu/g) for saw samples *before and after portioning* was found significantly greater in traditional compared to modern sector with p=.001 and p=.007, respectively. The chicken samples after chilling and after portioning process steps were found significantly greater in traditional compared to modern sector (p=.000). This study indicated that poultry portioning meat sector showed high bacterial load. The findings were of value for poultry industry for applying biosecurity and Hazard Analysis and Critical Control Point (HACCP) programs through poultry meat chain.

Keywords: Poultry; Slaughterhouse; Bacterial load; TBC; Portioning Operations; Thawing.

INTRODUCTION

The growing trend among consumers to believe that white meat is healthier than red meat has led to the popularity of poultry products. Over the past few decades, there has been a global rise in the consumption of poultry meat (Ukut et al., 2010). Nonetheless, epidemiological research indicated that food poisoning in humans is still mostly caused by poultry meat (Yashoda and others, 2001).

Microbial contamination is an inevitable result of the processing methods used when handling poultry carcasses. There is increased probability for the carcass to become contaminated at every stage of the process by either cross-contamination from other birds or microorganisms from the processing plant (Javadi & Safarmashaei, 2011).

Water, animal microbiota, and equipment surfaces can all lead to bacterial contamination (Yulistiani and Praseptiangga, 2019; Veluz et al., 2004; Pope and Cherry, 2000). Furthermore, broiler meat can become contaminated by airborne and environmental bacteria (Vihavainen et al., 2007).

Moreover, the skin of chicken carcasses and cuts comes into direct contact with surfaces, tools, and the air; as a result, the carcasses are quickly contaminated. Bacteria are found on the surface of fresh meat rather than within the flesh itself (Luber, 2009). On the other hand, bacteria can enter the muscles from processed foods such marinated meats (Warsow et al., 2008).

The main sources of contamination during the subsequent processing phases (deboning, cutting, mincing, and mixing) for the creation of meat-based foods are manipulators, air, and equipment surfaces. According to Alvarez-Astorga et al.

(2002), transformation activities increase the surface area of meat in contact with air and working surfaces. Consequently, as a result, transformed products have a greater number of bacteria than initial cuts (Alvarez-Astorga et al., 2002).

High bacterial load raises the danger of microbial spoilage, and total viable count in raw poultry is an indicator of the sanitary conditions of the processing plants under which the product is processed (Cohen et al., 2007; Javadi & Safarmashaei, 2011).

The primary chilling step for poultry carcasses in the meat chill chain in a slaughterhouse involves quickly cooling the meat carcasses after slaughter. This will ensure that the temperature at which the warmest point of the carcass reaches a minimum of 4°C. With the advancement of technology, this temperature can be reached in less than two hours for internal deep breast of carcasses, which is crucial in slowing the growth of microorganisms (Stella et al., 2021; James et al., 2006).

Freezing inhibits microbiological development, metabolic processes, and chemical reactions while maintaining the meat's quality. Nonetheless, it is also important to use the right thawing technique to guarantee the quality of the finished product (Mahmoud et al., 2021). In this context, it is crucial to note that chicken meat is susceptible to microbial growth, chemical deterioration, and significant water loss from dripping or dehydration during the thawing process. This might be because chicken meat's muscle fibers are thinner and softer than those of livestock (Akhtar et al. 2013; Sulleyman et al. 2018; Mehmood et al. 2020; El Jalil et al. 2020).

Additionally, thawing of chicken carcass in the refrigerator takes about 1-2 days depending on its weight (about 5hrs/half kg) (Xia et al. 2012).

Unfortunately, because it is so easy, many processing operations prefer to thaw meat at room temperature (on the counter) and because of the possibility of microbiological deterioration, food codes and regulations do not recommend it (Met et al. 2013). In some small commercial businesses, meat thawed at room temperature is restructured before being refreeze. This procedure is considered unsafe (USDA, 2013).

For successful trade, poultry meat must be preserved as an anaerobic vacuum-packed product in either refrigerated or frozen form at suitably low temperatures (Deards et al., 2014).

Food packaging nowadays strives to preserve aspects of quality, including physicochemical and microbiological parameters. In addition, utilizing freezing or cold storage in conjunction with packaging methods contributes to preserving a sufficient shelf life (Marsh & Bugusu 2007; Totosaus and Kuri, 2012).

Prior to transportation, it is crucial to keep the temperature of the chicken meat below 4°C at all times while it is being chilled, cut, deboned, and minced (Nastasijević et al., 2022).

Trucks for poultry meat transportation shall have a suitable refrigeration system that can keep meat at the proper temperature during distribution (Nastasijević et al., 2022).

Therefore, regulatory standards and monitoring the microbial intervention will guarantee ideal performance in decreasing the bacterial load from live hang to post-chil (Stopforth et al., 2007).

MATERIAL AND METHODS

- Study area and population:

This study was conducted in in Khartoum State from February 2018 to August 2020 in the three localities of Khartoum State (Khartoum, Omdurman and Bahri). It included 12 portioning meat operations of which 6 were from the traditional and 6 from modern poultry sectors.

Poultry production in Khartoum State has grown fast during the last decades. There are 23 traditional poultry slaughterhouses and 10 modern poultry companies for cutting poultry meat with a throughput of more than 31,400 bird/ hr.

The 10 modern poultry companies have additional processing facilities for cutting chicken, tallying, or classifying to wings, breast, drumstick, legs, and fillet then packaging and freezing.

Compared to the modern operations, the processing facilities in these traditional operations, so far, do not comply with the regulations in terms of good manufacturing and good hygienic practices.

Traditional portioning sector used to purchase frozen chicken from modern companies, transport them to their facilities in non-refrigerated vehicles. On arrival to the premises, chickens are emptied from their packages and placed in water on

the counter at room temperature for thawing, then they are cut up and repackaged (usually in non-compliant plastic bags). The final step is to refreeze them before being shipped to retail.

These methods followed in producing portioned poultry meat in the traditional sector arouse questions on the safety of poultry meat for consumers.

- **Sample size and sampling collection procedure**

A total of 288 swab samples were randomly collected for total bacterial count from different process steps in modern and traditional processing operations as shown in table (1):

Table 1: Sample type, sampling collection procedure and sample size in traditional and modern poultry portioning meat sectors

Step No.	Sample type	Process step	Total No.
1	water sample	directly from tap	12
2	hands swab	before starting work	24
3		during the work	24
4	saw swab	before starting work	12
5		during the work	12
6	work surfaces, utensils, and kitchenware (knives, and cutting boards)	before starting work	12
7		during the work	12
8	chicken meat swab	after chilling (before portioning from modern sector)	36
9	chicken meat swab	after portioning from modern sector	36
10	chicken meat swab	frozen chicken before portioning in traditional sector	36
11	chicken meat swab	defrosted chicken before portioning in traditional sector	36
12	chicken meat swab	after portioning in traditional sector	36
	Total sample		288

- **Sample collection for bacteriology**

Sterile metal template of 10 cm2 area was used to outline the swabbing area on the broiler carcasses. Sterile swab was rubbed in the breast and leg skin of chicken selected randomly before portioning and after portioning. The area was swabbed vigorously with sterile swab.

The organisms were removed from each swab by shaking for few minutes in 10 ml of sterile 0.5 % peptone water. The collected swabs of each sample were marked, numbered, and transported promptly on ice box to the laboratory of the College of Veterinary Medicine, University of Bahri for analysis.

The samples were examined for total bacterial count to assess level of bacterial contamination of the poultry cutting meat that would be supplied to consumers.

- **Total viable count**

The swab sample were placed in 10 ml of sterile 0.5 % peptone water then shaken with a vortex mixer for 30 seconds for uniform distribution of microorganisms. The standard pour plate technique was used. The serial dilution from (10^1 to 10^6) for all the samples was processed for total viable count. From last dilution, 0.1 ml was taken and spread evenly on plate count agar then incubated at 37ºC for 24 h. The counts were performed by colony counter and expressed as log10 cfu/cm2 (Harrigan, 1998).

- **Statistical Analysis**

The collected data was analyzed using SPSS version 20.0. The bacterial counts from direct serial dilution plating were transformed to $\log_{10}$ cfu /g. Descriptive statistics, frequency, mean was used. Chi-squared procedure was used to find association between variables, statistical analysis was performed using one sample t-test and paired sample t-test to determine significance in each parameter between traditional and modern portioning sectors ($P< 0.05$).

RESULTS

The mean of total count log10 (cfu/g) for water analysis was found to be not significantly greater in traditional (2.2 x106-±.2 x106-) compared to modern portioning sector (1.9 x106-± .3 x106-), with p=.395. The maximum bacterial load of water was (1.3 x106-) and (.8 x106-) in traditional and modern sectors, respectively, table (2).

Table 2: Mean of microbial load for water analysis from traditional and modern sectors:

Type of portioning	LOG_{10} (Mean± SE)	95% Confidence Interval for Mean		Max.	Min.	Sig.
		Lower Bound	Upper Bound			
Traditional	2.2 $x10^{6-}$±.2 $x10^{6-}$	1.6 $x10^{6-}$	2.7 $x10^{6-}$	1.3 $x10^{6-}$	2. 7 $x10^{6-}$	.395
Modern	1.9 $x10^{6-}$± .3 $x10^{6-}$	1.2 $x10^{6-}$	2.5 $x10^{6-}$	.8 $x10^{6-}$	2.7 $x10^{6-}$	
Total	2.0 $x10^{6-}$± .2 $x10^{6-}$	1.6 $x10^{6-}$	2.4 $x10^{6-}$	.8 $x10^{6-}$	2.7 $x10^{6-}$	

***P-value considered significant at less than 0.05 levels*

The mean of total count log_{10} (cfu/g) for hands samples *before portioning* was found to be not significantly greater in traditional (1.8 $x10^{6-}$±.2 $x10^{6-}$) compared to modern portioning (2.0 $x10^{6-}$±.2 $x10^{6-}$), with p=.368.

The mean of total count log_{10} (cfu/g) for hands samples *after portioning* was found to be not significantly greater in traditional (2.3 $x10^{6-}$±.1 $x10^{6-}$) compared to modern portioning (1.9 $x10^{6-}$±.1 $x10^{6-}$), with p=.094 (table 3).

Table 3: Mean of microbial load for hands samples taken from traditional and modern sectors before portioning and after portioning.

Process step	LOG10 (Mean± SE)	95% Confidence Interval for Mean		Min.	Max.	Sig.
		Lower Bound	Upper Bound			
Traditional before portioning	1.8 $x10^{6-}$±.2 $x10^{6-}$	1.3 $x10^{6-}$	2.3 $x10^{6-}$	.3 $x10^{6-}$	2. 7 $x10^{6-}$	.368
Modern before portioning	2.0 $x10^{6-}$±.2 $x10^{6-}$	1.7 $x10^{6-}$	2.4 $x10^{6-}$	.6 $x10^{6-}$	2.7 $x10^{6-}$	
Total	1.9$x10^{6-}$±.1 $x10^{6-}$	1.6 $x10^{6-}$	2.2 $x10^{6-}$	.3 $x10^{6-}$	2.7 $x10^{6-}$	
Traditional after portioning	2.3 $x10^{6-}$±.1 $x10^{6-}$	1.9 $x10^{6-}$	2.6 $x10^{6-}$	1.1 $x10^{6-}$	2. 7 $x10^{6-}$	.094
Modern after portioning	1.9 $x10^{6-}$±.1 $x10^{6-}$	1.6 $x10^{6-}$	2.2 $x10^{6-}$	1.1 $x10^{6-}$	2.7 $x10^{6-}$	
Total	2.1$x10^{6-}$±.1 $x10^{6-}$	1.9 $x10^{6-}$	2.3 $x10^{6-}$	1.1 $x10^{6-}$	2.7 $x10^{6-}$	

***P-value considered significant at less than 0.05 levels*

The mean of total count log10 (cfu/g) of work surfaces, utensils, and kitchenware samples *after portioning* was found not significantly greater in traditional (2.3 x106-±.2 x106-) compared to modern portioning (2.1 x106-±.2 x106-), with p=.339.

The mean of total count log_{10} (cfu/g) of work surfaces, utensils, and kitchenware samples *before portioning* was found to be not significantly greater in modern (2.1 $x10^{6-}$±.2 $x10^{6-}$) compared to traditional portioning operations (1.9 $x10^{6-}$±.2 $x10^{6-}$), with p=.543 (table 4) (table 4).

Table 4: Mean of microbial load for work surface samples taken from traditional and modern sectors before portioning and after portioning.

Process step	LOG_{10} (Mean± SE)	95% Confidence Interval for Mean		Min.	Max.	Sig.
		Lower Bound	Upper Bound			
Traditional before portioning	1.9 $x10^{6-}$±.2 $x10^{6-}$	1.4 $x10^{6-}$	2.4 $x10^{6-}$	1.2 $x10^{6-}$	2. 7 $x10^{6-}$	.543
Modern before portioning	2.1 $x10^{6-}$±.2 $x10^{6-}$	1.6 $x10^{6-}$	2.6 $x10^{6-}$	1.5 $x10^{6-}$	2.7 $x10^{6-}$	
Total	2.0$x10^{6-}$±.1 $x10^{6-}$	1.7 $x10^{6-}$	2.3 $x10^{6-}$	1.2 $x10^{6-}$	2.7 $x10^{6-}$	
Traditional after portioning	2.3 $x10^{6-}$±.2 $x10^{6-}$	2.0 $x10^{6-}$	2.6 $x10^{6-}$	1.9 $x10^{6-}$	2. 7 $x10^{6-}$	.339
Modern after portioning	2.1 $x10^{6-}$±.2 $x10^{6-}$	1.6 $x10^{6-}$	2.6 $x10^{6-}$	1.5 $x10^{6-}$	2.7 $x10^{6-}$	
Total	2.2$x10^{6-}$±.1 $x10^{6-}$	1.9 $x10^{6-}$	2.4 $x10^{6-}$	1.5 $x10^{6-}$	2.7 $x10^{6-}$	

***P-value considered significant at less than 0.05 levels*

The mean of total count log_{10} (cfu/g) for saw samples before portioning was found significantly greater in traditional (2.3 $x10^{6-}$±.1 $x10^{6-}$) compared to modern portioning (1.2 $x10^{6-}$±.2 $x10^{6-}$), with p=.001.

The mean of total count log_{10} (cfu/g) for saw samples after portioning was found significantly greater in traditional (2.5 $x10^{6-}$±.1 $x10^{6-}$) compared to modern portioning (1.9 $x10^{6-}$±.1 $x10^{6-}$), with p=.007 (table 5).

Table 5: Mean of microbial load for saw samples taken from traditional and modern sectors before portioning and after portioning.

Process step	LOG_{10} (Mean± SE)	95% Confidence Interval for Mean		Min.	Max.	Sig.
		Lower Bound	Upper Bound			
Traditional before portior	2.3 $x10^{6-}$±.1 $x10^{6-}$	1.9 $x10^{6-}$	2.7 $x10^{6-}$	2.1 $x10^{6-}$	2. 7 $x10^{6-}$	.001**
Modern before portioning	1.2 $x10^{6-}$±.2 $x10^{6-}$	.8 $x10^{6-}$	1.7 $x10^{6-}$	.4 $x10^{6-}$	1.6 $x10^{6-}$	
Total	1.7$x10^{6-}$±.2 $x10^{6-}$	1.3 $x10^{6-}$	2.2 $x10^{6-}$	.4 $x10^{6-}$	2.7 $x10^{6-}$	
Traditional after portioning	2.5 $x10^{6-}$±.1 $x10^{6-}$	2.1 $x10^{6-}$	2.8 $x10^{6-}$	2.1 $x10^{6-}$	2. 7 $x10^{6-}$	.007**
Modern after portioning	1.9 $x10^{6-}$±.1 $x10^{6-}$	1.6 $x10^{6-}$	2.2 $x10^{6-}$	1.7 $x10^{6-}$	2.4 $x10^{6-}$	
Total	2.2$x10^{6-}$±.1 $x10^{6-}$	1.9 $x10^{6-}$	2.4 $x10^{6-}$	1.7 $x10^{6-}$	2.7 $x10^{6-}$	

***P-value considered significant at less than 0.05 levels*

The mean of total count log10 (cfu/g) for chicken samples in modern was found significantly greater *after portioning* (1.6 $x10^{6-}$±.1 $x10^{6-}$) compared to *before portioning* (1.2 $x10^{6-}$±.1 $x10^{6-}$), with p=.000.

Means of chicken samples taken from traditional sector after thawing and *after portioning* 2.0 $x10^{6-}$±.1 $x10^{6-}$, 2.3 $x10^{6-}$ ±.1 $x10^{6-}$, consecutively were found significantly greater compared to *after freezing* (1.8 $x10^{6-}$±.1 $x10^{6-}$), with p=.000 as shown in table (6).

Table 6: Mean of microbial load for chicken samples from modern and traditional sectors at different process steps

Statistical test	Process step	Log10 (Mean± SE)	95% Confidence Interval for Mean		Sig.
			Lower Bound	Upper Bound	
Paired sample t-test	Modern: *after chilling*, and *before portioning*	1.2 $x10^{6-}$±.1 $x10^{6-}$	.2 $x10^{6-}$	.3 $x10^{6-}$	.000**
	Modern: *after* portioning	1.6 $x10^{6-}$±.1 $x10^{6-}$			
one sample t-test	Traditional: *after* thawing	2.0 $x10^{6-}$±.1 $x10^{6-}$	1 .8 $x10^{6-}$	2 .2$x10^{6-}$	.000**
one sample t-test	Traditional: *after* portioning	2.3 $x10^{6-}$±.1 $x10^{6-}$	2 .2 $x10^{6-}$	2 .5$x10^{6-}$	.000**
one sample t-test	Traditional: *after* freezing	1.8 $x10^{6-}$±.1 $x10^{6-}$	1 .6 $x10^{6-}$	2 .0$x10^{6-}$	.000**

***P-value considered significant at less than 0.05 levels*

DISCUSSION

The objective of this study was to investigate the bacterial load in portioned poultry meat operations in Khartoum State, Sudan.

The findings of this study indicated that contaminated water was found to be not significantly greater in traditional compared to modern sector with p=.395**.** This may be attributed to the fact that generally traditional sector in developing nations suffers from inadequate hygiene and sanitation practices, outdated or substandard facilities and equipment that can exacerbate contamination risks (Ovuru et al., 2024).

Such water does not fulfill international requirements for drinking water will contaminate the meat during washing processes (Canadian Food Inspection Agency, 2010). This result, however, was higher than that of obtained by Pius Tanga (2013), who reported a mean value of 4.3 log10 cfu/ml in Morogoro Municipality in Tanzania.

One of the most efficient ways to reduce contaminations off workers' hands is to wash them with soap and water (CDC, 2020). Furthermore, washing prevents pathogen cross-contamination when preparing chicken (Pierrine Didier et al., 2021). It is worth noting that hand hygiene is a recognized strategy to reduce the spread of diseases by healthcare personnel (WHO, 2009).

The higher contamination of workers' hands in this study may be due to lack of monitoring of hygienic practices of workers. However, higher contamination of workers' hands in traditional slaughterhouses in Khartoum State was recorded by Ekram et al. (2023) who stated that higher variation in contamination of workers hands was recorded after chilling process step (clean zone) in both automatic and manual slaughterhouses in Khartoum State (0.3 ±1.7 Vs 12.5±11.1), respectively.

Surface microbiological analysis of meat and meat products provides a useful index of the extent of microbial contamination since this is the most likely area to be crossed contaminated during handling and processing (Cohen et al., 2007).

The present study showed that the mean of total count log10 (cfu/g) for work surfaces, utensils, and kitchenware samples was found to be not significantly greater in modern compared to traditional portioning operations before and after portioning. This may be due to poor sanitation and handling during processing (Mustafa et al., 2016).

The findings of this study revealed that the mean of total bacterial count for saw samples before and after portioning was found significantly greater in traditional compared to modern portioning operations with p= .001 &.007, respectively. This might be due to unhygienic practices in traditional sector. In addition, this high bacterial load is attributed to the fact that during the cutting process, the microorganisms disseminate from the carcass surface to the cut meat as the cutting operation proceeds (Warsow et al., 2008). Similar results were obtained by Jung-Hyun Kim & Dong-Gyun Yim (2017) who found that the highest APC values of samples from meat processing plants were obtained from cutting machines, and knives.

Based on findings from this study, the sources of poultry meat contamination originated from contaminated working surfaces, equipment and workers' hands used in the processing.

Mustafa et al. (2016) reported that several factors contribute to meat contamination in Khartoum State, which are obviously seen from the poor handling during processing. Inadequate chilling method was another factor in preventing the proliferation of contamination (Cason et al., 2004).

Aerobic plate counts are a widely accepted measure of the general degree of microbial contamination and the hygienic conditions of meat processing plants (Cohen et al., 2007).

Findings from this study revealed that the mean of total count for chicken samples in the traditional sector after freezing process step was 1.8 $x10^{6-}$±.1 $x10^{6-}$. Observation showed that method of processing such as thawing, cutting, and packaging the products all occurred at room temperature. Additionally, high levels of microbiological contamination may be due to the absence of implementation of GMPS and GHPS (WHO, 2000).

This finding was not away from that obtained by Hassan- Ola (2015) who recorded 1.7x103cfu/g as a mean value of TCC in chicken meat.

However, this finding is lower than the acceptable upper limits for aerobic plate counts (6.7 log10 cfu/g for fresh poultry meat as mentioned by Cohen et al. (2007).

Higher total bacterial counts (5.06515) for microbiological quality of poultry meat marketed in Tabriz were reported by Javadi and Safarmashaei (2011) Similarly, Sengupta et al. (2012), Omorodion and Odu (2014), and Bhandari et al. (2013) have reported higher counts of total aerobic bacteria 6.39 log CFU/g, 5.96 log CFU/g and 7.24 log CFU/g, respectively in market chicken meat.

Moreover, Berrang and Dickens (2000) noted APC pre-chill and post-chill carcass counts of mean log 3.6 CFU/mL and 2.9 CFU/mL. As for pre-chilling, Bauermeister et al. (2008) recovered APC mean log CFU/mL of 4.24 from commercially processed carcasses.

It is important to mention that traditional thawing methods of meat at room temperature is another factor that raise bacterial load. This study indicated that the mean of chicken samples taken from traditional sector after thawing was found to be (2.0 $x10^{6-}$±.1 $x10^{6-}$). The highest bacterial counts of frozen chicken meat thawed over counter-top agreed with the findings of He et al. (2013); Leygonie et al. (2012) and Akhtar et al. (2013) who observed that less uniform thawing at relatively high temperatures (20-30°C) with increased moisture and nutrients from drip loss provides an excellent medium for microbial growth and produce unacceptable meat.

CONCLUSION

This study concluded that the degree of microbial contamination during processing of poultry portioning was higher than the accepted international standard. Based on findings from this study, the sources of poultry meat contamination originated from poor handling during processing, contaminated working surfaces, equipment and workers' hands, and inadequate chilling method. Imposing good manufacturing practices and good hygienic practices on traditional poultry portioning sector should be mandatory. Poultry slaughterhouses, poultry portioning operations and meat factories should be controlled and audited by the same competent authority.

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Conflict of interest

The authors declare that there is no conflict of interest.

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Ethical standards

The manuscript does not contain clinical studies or patient data.

Author contributions

This work was carried out in collaboration between both authors. Material preparation, data collection, conduction of laboratory analysis, and contribution to drafting the initial manuscript were performed by Salma Yhia Salih Suliman. The study conception and design, general supervision over the research and the edition and reviewing of the final manuscript were performed by Elniema A. Mustafa.

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