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Goat carcass microbial investigation in Modjo Export Abattoirs, Ethiopia

Abraha Negash[1*] and Karanfil Olga[2]

[1]Ethiopian Meat and Dairy Industry Development Institute, Ministry of Trade and Industry, Ethiopia.
[2]DVM, Debrezeit, Ethiopia.

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The study was conducted to investigate microbiological quality of goat carcass in the Ethiopian export abattoirs, located in Modjo from January to April, 2017. Swabbed samples of 180 were collected from three abattoirs: 144 were from 12 carcass of three anatomical sites (thorax, hind and foreleg), 24 employees' hands and apron, and 12 carcass washing water to determine coliform counts (CFU), *Escherichia coli* and total plate counts (TPC) as indicator organisms focusing carcass decontamination effects of post washing, acid spray and chilling. The mean result for TPC log/cm^2 was 4.22, 4.03 and 3.56 for Abattoir 1, 2 and 3, respectively. Ranging from 1.7 to 7.4 and mean 3.95 ± 1.3 TPC log/cm^2 for the water, employees' hands and apron. There was 1.9±1.006 TPC counts/cm^2, 1.38±0.874 CFU counts/cm^2 and 1.28±0.799 *E. coli*/cm^2 mean in the carcass with statistically significant difference ($p<0.05$) level that meat handling procedures enabled the abattoirs with minimal microbial counts from washing to chilling. Strongly significant correlation ($p<.05$) among the microbials was observed. The study confirmed the abattoirs slaughtering procedures enabled to deliver safe carcass with very minimum microbial counts that 96.5% of the carcass was safe cumulative wise of which 84% was categorized in excellent standards. Carcass contaminating bacteria should be determined.

Key words: Microbial, goat carcass decontamination, Ethiopian export abattoirs.

INTRODUCTION

The export of meat and meat products is an important element in the Ethiopian economy as there is an ever increasing demand for meat and meat products worldwide including beef, sheep, goat, processed meats, etc., both as fresh and frozen products. Ethiopia has the opportunity to respond to this international demand and increase its market share in what is a very lucrative trade, subject to it meeting the stringent requirements demanded

*Corresponding author. E-mail: abrahane12@gmail.com. Tel: +251114308618

Abbreviations: APC, Aerobic plate count; **SPC**, standard plate counts; **TPC**, total plate counts; **TVC**, total viable counts; **CFU**, coliform counts; **ECC**, Escherichia coli counts.

by livestock and meat importing countries. Because of its composition, meat of all sorts is highly susceptible to microbiological and chemical contamination. Unless derived from healthy animals, handled % processed in a proper manner, it may present a serious health hazard to consumers. To prevent this, importing countries are setting high standards for both product preparation and final product involving the most strict health and quality controls and scientific inspection. Therefore, it is essential for Ethiopia to comply with the requirements of importing countries. To do otherwise, results in costly rejections and loss of product (Nega, 2015). The safety of meat has been at the forefront of societal concerns in recent years, and indications exist that challenges to meat safety will continue in the future (Sofos, 2008).

Wholesome meat must be produced hygienically, free from pathogenic organisms and retains its natural state and nutritive value. Monitoring the prevalence of microorganisms of hygienic interest in primary production at abattoirs makes data available for effective control of pathogenic agents before they entered the food (Bhandare et al., 2010). Raw meat is an ideal medium for bacterial growth; this is due to its high moisture contents. It is rich in protein, fermentable carbohydrate (glycogen), favorable pH and other growth factors (Magnus, 1981). Mayr et al. (2003) showed that meat provides an ideal condition for the growth of different spoilage bacteria making meat very perishable. Indicator organisms are bacteria that are used to provide evidence of poor hygiene, inadequate processing or post-process contamination of foods. They are often chosen because they are relatively quick and simple to detect. Their absence in food provides a degree of assurance that the hygiene and food manufacturing process has been carried out appropriately, whereas their presence usually indicates that a potential problem or failure in the process has occurred (Mead, 2007).

Microbiological tests are important in governmental food inspection to enforce legal requirements, international trade to determine compliance with microbiological standards, commercial relationships between trading partners to ensure that agreed microbiological specifications are met, the food industry to maintain quality control and process requirements, academic areas for research purposes, and reference laboratories to confirm the results of other laboratories and to provide surveillance data (Mead, 2007). Both total viable counts (TVC) and *Escherichia coli* testing are necessary to understand the process of slaughter, dressing and chilling. Testing for other organisms may be specified by specific customer (AS 4696-2002). Testing foods and water for coliform has remained popular, not least because specific guidelines and regulations demand coliform testing. Microbiological criteria are used at any stage in the food chain to assess the acceptance of lots of raw material or finished product. They are based on the absence/presence of certain microorganisms or quantitative limits per units. Product counts were obtained using methods set out based on surveys of Australian meat (AS 4696-2002) descriptions used: Excellent, Good, Acceptable and Marginal for microbial levels listed:

If *E. coli*/cm^2 is a) zero- excellent; b) 1-10= good; c) 10-100= acceptable; d) 100-1000= marginal; e) *E. coli*/cm^2 more than 1000 is not acceptable.

If total plate counts (TPC)/cm^2 is a) <1000= excellent; b) 10^3-10^4= good; c) 10^4-10^5= acceptable; d) 10^5-10^6-= marginal; e) TPC/cm^2 more than 10^6 is not acceptable.

If coliform counts (CFU)/cm^2 is a) zero= excellent; b) 1-10= good; c) 10-100= acceptable; d) 100-1000= marginal; e) *E. coli*/cm^2 more than 1000 is not acceptable.

Coliform more than 1000 is unacceptable. For water samples, detection of any coliform unit is undesirable.

The food industry uses microbial test as an indicator to determine the overall level of sanitation within the manufacturing and distribution processes and to determine whether the processing kill step was significant. The higher the microbial load found in TPC is, the greater is the possibility that the processing environment is not clean or that the process was not sufficient enough to kill an adequate number of the organisms present. TPC is a good indicator for the overall bacterial load of meat and meat products. Critical hygienic dimensions are reached when the total number of bacteria on fresh meat lies between 10^4 and 10^5/g. *E. coli* are bacteria present in intestines of human and animal. Shiga toxin-producing strains of *E. coli* or STECs are responsible for most food-related *E. coli* infections. *E. coli* O157:H7 and other STECs like *E. coli* O145 and *E. coli* O121:H19 produce a toxin called Shiga toxin, which causes illness in humans (Nagarajan et al., 2018). *E. coli* were enumerated on Eosin methylene blue agar by plating an appropriate dilution on plates followed by aerobic incubation at 37°C for 24 h. After incubation, *E. coli* were counted as colonies with distinct metallic sheen (Bhandare et al., 2007).

Objective

Therefore, the aim of the study was to investigate HACCP/GMPs practices and evaluate the microbial distribution of goat carcass at export abattoirs.

Specific objectives

(1) To satisfy regulatory requirements providing customers with information on product quality,

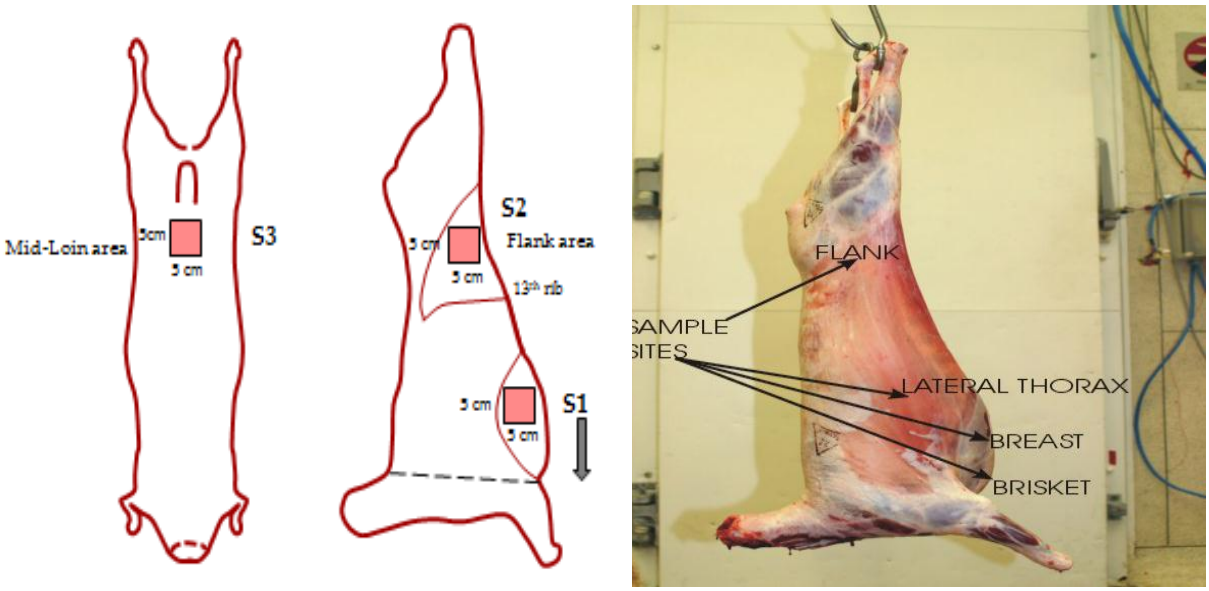


Figure 1. Sampling sites for small stock.
Source: Meat standard committee (AS 4696-2002).

(2) To monitor process control and approve the exportable carcass quality,
(3) To investigation poor performance with a view to improve the process of the abattoirs gauging the effectiveness of cleaning procedures,
(4) To assess product against a national and international benchmark,

MATERIALS AND METHODS

Sampling procedures

A total number of 180 cotton swapped samples were collected equally from three abattoirs, of which 144 were from thorax, hind and fore limbs, 12 water samples and 12 aprons and 12 employee palm. Samples were collected aseptically in sterile containers and brought to the laboratory within 30 to 45 min using ice box. After collection, bacteriological analysis of the samples were performed to assess the selected microbial attributes such as TPC, CFU and *E. coli* in goat carcass of different sources by using Plate Count (PC) agar, MacConkey (MC) agar to find out the sanitary quality of goat carcass of Ethiopian Export Abattoirs. Investigations were carried out over the period January to March, 2017, during the production of goat carcass for export. The surface to be examined was swabbed twice using parallel strokes at right angles to the first strokes. Care was taken to swab the whole of the predetermined area. After swabbing, the swabs were transferred to the respective tubes containing the 5 ml of sterile 0.1% peptone water. An area of 100 cm^2 marked with a sterile frame of 10 cm × 10 cm on each site of the carcass was rubbed for 30 s and swabs were transferred to a screw-capped test tube containing 10 ml of sterile maintenance medium 0.1% peptone water (Hamdan et al., 2019) (Figure 1).

The research materials included cotton swabs, ice boxes, alcohol, amenities, water, and camera and 12 samples of fresh goat carcass were randomly assessed from 3 major export abattoirs in Modjo areas after carcass was washed and organic acid sprayed and after 24 h chilling. The samples were collected from different portions of carcasses and 36 abattoir employees' hands and apron who engaged in meat washing along with the water they used to wash. The samples were collected once/week from each export abattoir. The samples were aseptically collected in different clean polyethylene bags and were transferred immediately to the laboratory for bacteriological quality assessment. The meat samples were collected in aseptic containers labeled and transported in an ice box for 30 min, subjected to qualitative or quantitative analysis for bacterial zoonotic pathogens indicator organisms.

Statistical model for microbial count

The data on TPC, CFU and *E. coli* obtained from the study carcass surface were analyzed in completely randomized design/CRD using SPSS and Excel. Data collated were analyzed using IBM SPSS Statistics version 20 (IBM Corporation, 2011). Simple means, percentages and frequencies were computed. Means were compared using Analysis of Variance (ANOVA) and Chi-squared test was used to determine associations.

$$Y_{ijk} = \mu + T_i + S_j + (TS)_{ij} + E_{ijk}$$

where *Y*ijk = microbial count, μ = overall mean, *T*i = effect of treatment (before and after treatment), and *S*j = effect of site (1 = Thorax, 2 = Hind limb and 3 = Fore limb), (TS)ij = interaction between treatment and site, *E*ijk = random error.

Microbiological analysis

For food control purposes, the organisms in question are often

Table 1. CFU, *E.coli* & TPC in goat carcass with t- values and interval ranges.

Variable	Test Value=0.05					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence interval of the difference	
					Lower	Upper
CFU/cm^2	18.003	143	0.000	1.311	1.17	1.46
E. coli count/cm^2	18.540	143	0.000	1.235	1.10	1.37
TPC count/cm^2	22.107	143	0.000	1.853	1.69	2.02

Table 2. ANOVA for comparative mean and significance of CFU, *E.coli* & TPC of fresh carcass.

Variable		Sum of Squares	df	Mean Square	F	Sig.
CFU/cm^2	Between groups	12.500	11	1.136	0.880	0.567
	Within groups	46.500	36	1.292		
	Total	59.000	47			
E. coli count/cm^2	Between groups	13.562	11	1.233	1.296	0.266
	Within groups	34.250	36	0.951		
	Total	47.812	47			
TPC log/cm^2	Between groups	15.729	11	1.430	1.572	0.149
	Within groups	32.750	36	0.910		
	Total	48.479	47			

referred to as 'markers' of the microbiological quality of food, and they are seen as a key indicator/analytical tool for validating compliance with legislation. Where their occurrence in foods is associated with the possible presence of pathogens that are related to them taxonomically, physiologically and ecologically; they are termed 'index' organisms/marker. Here, it refers to any suitable organism that is deliberately added at a pre-determined level to a carcass or item of equipment in a slaughter or processing line in order to determine a possible route of cross-contamination, or to verify that a particular control measure is limiting its spread and the marker organism is one that is readily distinguished from all others present or can be isolated specifically and enumerated on a selective agar medium (Mead, 2007). Total bacterial count load is exemplified by measuring the amount heterotrophic organisms. These organisms can be tested by APC, TPC, TVC or SPC that are acronyms used fairly interchangeably by industry and testing laboratories alike, although TPC is the most common. The total aerobic plate count is useful for indicating the overall microbiological quality of a product and, thus, is useful for indicating potential spoilage in perishable products. The aerobic plate count is also useful for indicating the sanitary conditions under which the food was produced and/or processed (FAO, 2007).

The control of food safety and quality is an integral part of national programs for development. National food control systems are designed to protect the health and welfare of the consumer, to promote the development of trade in food and food products, and to protect the interests of the fair and honest food producer, processor or marketer against dishonest and unfair competition.

Microbiological examination of samples, TVCs and ECs were determined by standard plate count methods according to the criteria specified by ISO 4833:2003. Each sample homogenate swabbing was then diluted decimally in peptone water, and 1 ml aliquots were added to suitable Petri dishes, reaching a 10^{-6} dilution (TVC) and a 10 dilution (EC). Samples were analyzed within 24 h of collection. The culture media were plate count agar for TVCs and violet red brilliant green agar for *ECs*. PCA plates were incubated at 37°C for 48 h before colonies were counted. Enterobacteriaceae were incubated at 37°C for 24 h. The detection limit was 0.50 CFU/cm^2 for all ovine carcasses.

Water samples 3×4=12 totally from carcass washing were collected for bacteriological analysis according to EC (2007) to estimate the number of Coliform bacilli in 100 ml of water using the presence-absence method. The method was chosen because the focus was the positive detection of *E. coli*, regardless of quantity; as the guideline for *E. coli* in drinking water is none per 100 ml, and qualitative results are sufficient for protecting public health (Nouichi, 2009; Verhille, 2013). For more than a hundred years, *E. coli* and coliform bacteria have been used as bacterial indicators of faecal pollution in water supplies. Currently, total coliform and *E. coli* are the most common microorganisms used as the primary indicator to assess water quality (Wen et al., 2020). Their use relates to the occurrence of such organisms in the faeces of man and a wide variety of warm-blooded animals, and the fact that the bacterial pathogens of greatest concern in water (Mead, 2007).

RESULTS AND DISCUSSION

The mean result for fresh goat carcass quality as determined for CFU, *E. coli* and TPC in three abattoirs of 144 samples from the three carcass sites was 1.36, 128 and 1.90 count/cm^2, respectively. The upper and lower values are higher for TPC than CFU and *E. coli* and it was statistically significant at $p<0.05$. The F-distribution is also highest for TPC (Tables 1 and 2).

The variability result of between groups due to

Table 3. Mean ± standard error of CFU, *E. coli* and TPC in Abattoirs 1, 2 and 3.

Microbial	Abattoirs		N	Mean	Std. error	95% Confidence interval for mean		Minimum	Maximum	Between-component variance
						Lower bound	Upper bound			
Coliforms (CFU/cm^2)	1		48	1.75±1.12	0.162	1.42	2.08	1	5	0.099
	2		48	1.17±0.69	0.100	0.97	1.37	1	5	
	3		48	1.17±0.6	0.086	0.99	1.34	1	4	
	Total		144	1.36±0.87	0.073	1.22	1.51	1	5	
	Model	Fixed effects/treatments	-	-	0.070	1.22	1.50	-	-	
		Random effects/error or residual	-	-	0.194	0.52	2.20	-	-	
E. coli count/cm^2	1		48	1.56±1	0.146	1.27	1.86	1	4	0.047
	2		48	1.19±0.7	0.106	0.97	1.40	1	4	
	3		48	1.1±0.5	0.074	0.95	1.25	1	4	
	Total		144	1.28±0.8	0.067	1.15	1.42	1	4	
	Model	Fixed effects	-	-	0.065	1.16	1.41	-	-	
		Random effects	-	-	0.141	0.68	1.89	-	-	
Total Plated log/cm^2	1		48	1.77±1	0.147	1.48	2.07	1	4	-0.003
	2		48	1.9±1	0.150	1.59	2.20	1	4	
	3		48	2.04±0.97	0.140	1.76	2.32	1	4	
	Total		144	1.9±1	0.084	1.74	2.07	1	4	
	Model	Fixed effects	-	-	0.084	1.74	2.07	-	-	
		Random effects	-	-	0.084[a]	1.54[a]	2.26[a]	-	-	

treatments was smaller than within groups/errors or residues. Statistically remarking the population effect is small/inferior, justifying the difference could be due to chance. The F-test for TPC, *E. coli* and CFU were small (close to 1.0) indicating least effect, but comparatively higher F test values for TPC and least for CFU.

Table 3 remarked many of the descriptive statistics including the fixed and random effects of CFU, TPC and *E. coli* in abattoirs 1, 2 and 3. There is significant difference in CFU and *E. coli* in abattoir 1 but not in TPC log/cm^2 mean that is reversed from abattoir 3 to 2 to 1, recommending abattoir 1 HACCP team and top management for due attention in both *E. coli* and CFU effects though comparatively safe in TPC. The research result warns abattoir 3 that scored higher TPC. There was significantly higher mean ($P<0.05$) in TPC/cm^2 (1.9+1) but least in *E. coli*/cm^2 (1.28+0.8) in the carcass of the abattoirs.

CFU strongly (0.54) correlate with *E. coli* and weakly correlate (0.21) with TPC. Coliform significantly correlate with *E. coli* at $P< 0.01$ and $P< 0.05$ significant level with TPC. TPC was positively (0.13) correlated with *E. coli* weakly. So strong correlation in between coliform and *E. coli* has severe consequence in meat quality and risk in consumers' health (Table 4).

TPC log/cm^2 values for the water quality, employee apron and hands in the clean area are shown in Table 5 and ranged from 1.7 to 7.4 with 3.95 mean. There was no detection of CFU and *E. coli* in the carcass washing water in abattoirs 1, 2

Table 4. Correlations of Coliform, *E.coli* and Total Plate counts.

Correlation		(CFU/cm^2	*E. coli*/cm^2	TPC log/cm^2
Coliforms (CFU/cm^2)	Pearson Correlation	1	0.543**	0.207*
	Sig. (2-tailed)		0.000	0.013
	N		144	144
E. coli count/cm^2	Pearson Correlation		1	0.130
	Sig. (2-tailed)			0.119
	N			144
Total Plate count log/cm^2	Pearson Correlation			1

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

Table 5. Mean ± standard deviation of TPC log/cm^2, water quality, employee apron and hands in the clean area.

Variable	N	Minimum	Maximum	Sum	Mean
TPC log/cm^2	36	1.70	7.40	141.65	3.95±0.22

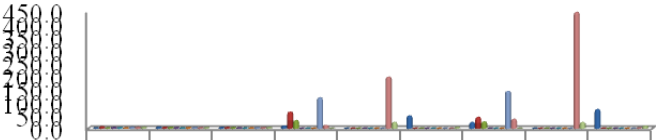
and 3, but significantly higher TPC log/cm^2 in abattoir 1 (3.1), abattoir 2 (2.2) and abattoir 3 (1.86), although it was categorically excellent distribution. Comparatively, in abattoir 1, there was higher bacterial contamination since both CFU and *E. coli* were in marginal category in employee apron working in clean area, followed by abattoir 2 where TPC log/cm^2 was marginal category that demands action for strict correction measures of HACCP implementation (Figure 3). Abattoir 1 scored the highest TPC log/cm^2 in washed thorax and chilled hind limb, thorax and forelimb that fall in marginal category; followed by abattoir 2 that scored higher TPC, besides to the significant difference in *E. coli* and CFU in the chilled thorax and hind limb of carcass site. Abattoir 1 scored the highest coliform and *E. coli* counts/cm^2 in the clean area employee apron, followed by abattoir 2 in employee swapped palm. Worker palm from clean area was higher in abattoir 3 followed by abattoir 2 that scored higher counts in the apron from clean area in TPC (Figure 2).

The study resulted in pair wise comparisons of CFU, *E. coli* and TPC in abattoirs 1, 2 and 3, and there was a significant difference between CFU and *E. coli* ($p < 0.05$). The mean difference between each pair was 0.583, 0.458 and 0.207, respectively for CFU, *E. coli* and TPC (Table 6).

The frequency of *E. coli* in the carcass was 87.5% that supported the distribution category excellent for no detection (Table 7). The maximum values for CFU/cm^2 and *E. coli*/cm^2 were 500 and 800, respectively. The excellent category out weighed in all the bacterial forms followed by good, acceptable and marginal sequentially for TPC, but for CFU, acceptable, marginal and unacceptable were followed. The majority are located in center of normal curve (Figure 4).

When looking at the box plot, the similarities and differences of the three abattoirs in TPC distributions were striking. Comparing the interquartile ranges and quartiles that Abattoir 3 was in the lower 25 percentile and Abattoir 1 stood at the upper 75 percentile of the box plot remarking that the median (center) was roughly similar for TPC log/cm^2. The 25, 50 and 75% were 2.84, 3.97 and 4.7, respectively while the mean and standard deviation was 3.94+1.29. Note that the result provides more intuition about variability by interpreting small variability as stability, and large variability as lack of stability. The center of the distribution is more meaningful as a typical value for the distribution when there is little variability (little “noise”) around it. In abattoirs 1 and 2, the length of the whiskers far exceeds the length of the box. A well proportioned tail would give rise to whiskers about the same length as the box, or maybe slightly longer. The box plot indicated that mean TPC log/cm^2 increases from abattoir 3 to 1, that the mean TPC log/cm^2 was 3.56, 4.03 and 4.22, respectively (Figure 5).

The carcass decontamination effects of TPC log/cm^2 in carcass sites displayed in comparative abattoirs 1, 2 and 3. Thoracic area after carcass washing and chilling and hind limb after chilling in abattoir 1, and hind limb after carcass washing in abattoir 2, were the highest in TPC. Figure 7 remarked that abattoir 1 leads thoracic area in many measures of carcass handling procedures that recalling caution particularly chilling room case that HACCP team should implement. There was a drop of TPC



	Total plate Log/cm²			*E. coli* count/cm²			Coliforms count (CFU/cm²)		
	1	2	3	1	2	3	1	2	3
Hind limb washed	2.8	6.4	4.4	10	0	50	25	0	75
Thorax washed	7.4	4.9	4.5	65	0	0	45	0	0
Forelimb washed	2.7	4.7	4.1	32.5	0	0	27.5	0	0
Hind limb Acetic acid sprayed	4.4	3.0	2.8	0	0	0	0	0	0
Thorax Acetic acid sprayed	3.9	2.5	1.7	0	0	0	0	0	0
Forelimb Acetic acid sprayed	2.3	3.4	2.5	0	0	0	0	0	0
Hind limb chilled	5.7	4.5	3.7	120	0	0	145	0	0
Thorax chilled	5.4	3.2	3.5	12.5	200	0	37.5	450	2.5
Forelimb chilled	5.3	3.8	4.4	0	25	5	0	25	10

Figure 2. Microbial status of carcass sites of Abattoirs 1, 2 and 3.

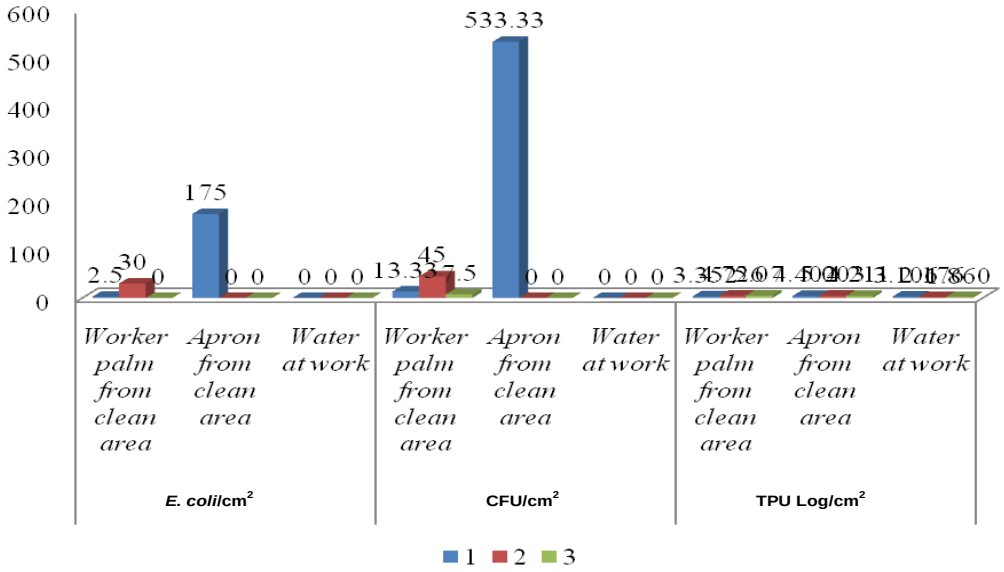


Figure 3. Microbial status of water used for carcass washing and worker's apron and palm in the clean area of Abattoirs 1, 2 and 3.

load from washing to acetic acid spray to chilling slightly in thorax, hind and forelimb in abattoirs 1, 2 and 3, with the exception in hindlimb of abattoir 1 that contradictively increased from washing to acid spray and chilling, alerting HACCP team and top mangement for correction.

In abattoir 1, there was increasing order from washing to acetic acid spray to chilling in the hind limb (Figure 6). TPC log/cm^2 declined from washing to acetic acid sprayer, but slightly increased post chilling, warning chillers efficiency.

Table 6. Multiple comparisons of CFU, TPC and *E. coli* in abattoirs 1, 2 and 3.

Dependent variable		(I) Abattoirs	(J) Abattoirs	Mean difference (I-J)	Std. error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
CFU/cm^2	LSD	1	2	0.583*	0.170	0.001	0.25	0.92
			3	0.583*	0.170	0.001	0.25	0.92
		2	1	-0.583*	0.170	0.001	-0.92	-0.25
			3	0.000	0.170	1.000	-0.34	0.34
		3	1	-0.583*	0.170	0.001	-0.92	-0.25
			2	0.000	0.170	1.000	-0.34	0.34
E. coli count/cm^2	LSD	1	2	0.375*	0.159	0.020	0.06	0.69
			3	0.458*	0.159	0.005	0.14	0.77
		2	1	-0.375*	0.159	0.020	-0.69	-0.06
			3	0.083	0.159	0.601	-0.23	0.40
		3	1	-0.458*	0.159	0.005	-0.77	-0.14
			2	-0.083	0.159	0.601	-0.40	0.23
TPC log/cm^2	LSD	1	2	-0.125	0.205	0.544	-0.53	0.28
			3	-0.271	0.205	0.190	-0.68	0.14
		2	1	0.125	0.205	0.544	-0.28	0.53
			3	-0.146	0.205	0.479	-0.55	0.26
		3	1	0.271	0.205	0.190	-0.14	0.68
			2	0.146	0.205	0.479	-0.26	0.55

*The mean difference is significant at the 0.05 level.

Table 7. Frequency value of swapped carcass part microbial counts.

Microbial type	Safety level	Frequency	Percent	Valid percent	Cumulative percent
Coliform (CFU/cm^2)	Excellent	121	84.03	84	84
	Good	1	0.69	0.7	84.7
	Acceptable	17	11.81	11.8	96.5
	Marginal	3	2	2.1	98.6
	Unacceptable	2	1.39	1.4	100
	Total	144	100.00	100	-
Total plate count (log/cm^2)	Excellent	67	46.53	46.5	46.5
	Good	37	25.69	25.7	72.2
	Acceptable	27	19	18.8	91
	Marginal	13	9.03	9	100
	Total	144	100.00	100	-
E. coli (count/cm^2)	Excellent	126	87.50	87.5	87.5
	Good	3	2.08	2.1	89.6
	Acceptable	7	4.86	4.9	94.4
	Marginal	8	5.56	5.6	100
	Total	144	100.00	100	-

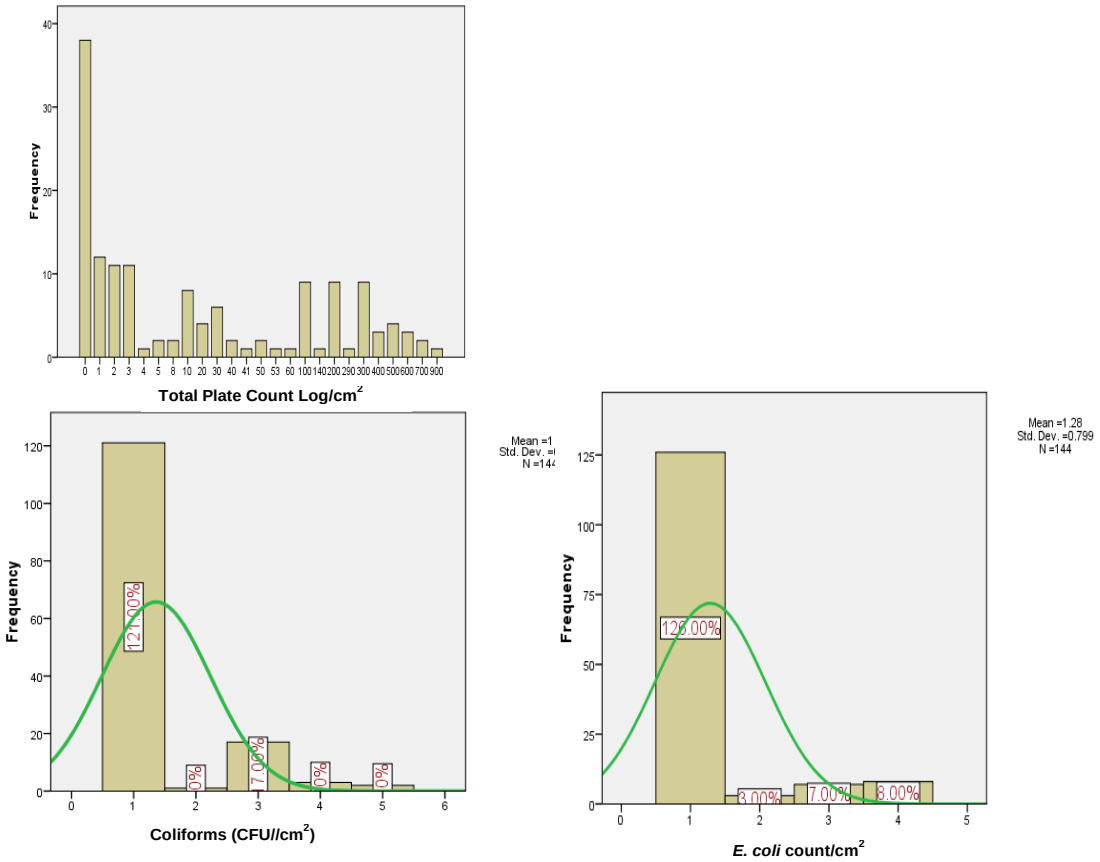


Figure 4. The microbial category distribution safety were acceptable based on international standards in cumulative 91% TPC, 96.5% CFU and 94.4% *E. coli.* a, TPC log/cm^2 distribution category in the carcass, from 0=no detection (46.5% excellent) to 900 (9% marginal). b. CFU/cm^2 from 84% excellent for no detection to 1.39% unacceptable. c. *E. coli*/cm^2 from 87.5% excellent for no detection to 5.56% marginal.

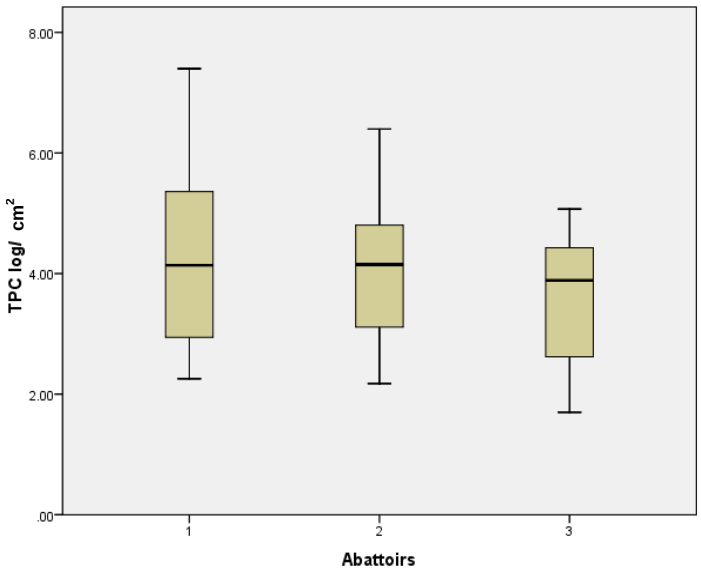


Figure 5. TPC log/cm^2 distribution in abattoirs 1, 2 and 3.

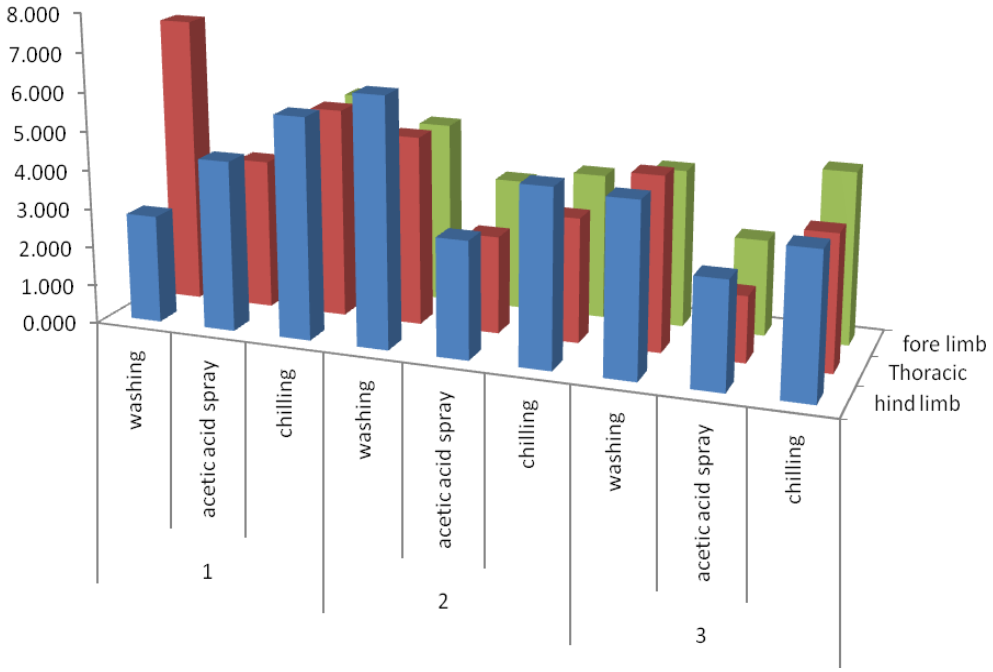


Figure 6. TPC log/cm^2 in Abattoirs 1, 2 and 3 goat carcass parts swapped post washing, acetic acid spray and chilling.

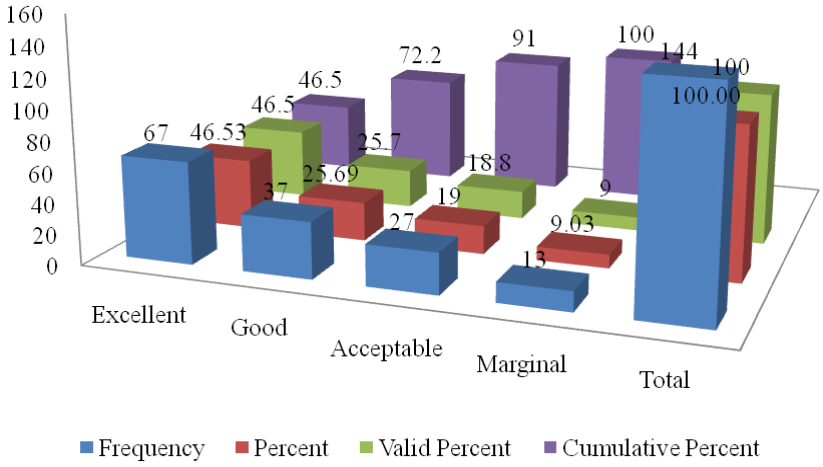


Figure 7. TPC log/cm^2 carcass safety category distribution.

Abattoirs 1, 2 and 3 performance of TPC frequency indicated that the carcass dressing practices were apt and of international standards (Figure 8).

Figure 8 shows that CFU wise, 96.5% of the carcass was safe cumulative wise of which 84% was excellent, 0.7% good, 11.8% acceptable, and 2.1% marginal where action is required. However, apron from clean area in abattoir 1 and acetic acid sprayed and chilled thorax in abattoir 2 in 1/4 sampling days scored 1.39% unacceptable result that is great time to warn the HACCP team and the abattoirs' top management to strictly implement HACCP procedures for quality meat products routinely.

Figure 9, indicated that *E. coli* wise 94.4% of the carcass was safe cumulatively of which 87.5% was excellent, 2.1% good, 4.9% acceptable and 5.6%

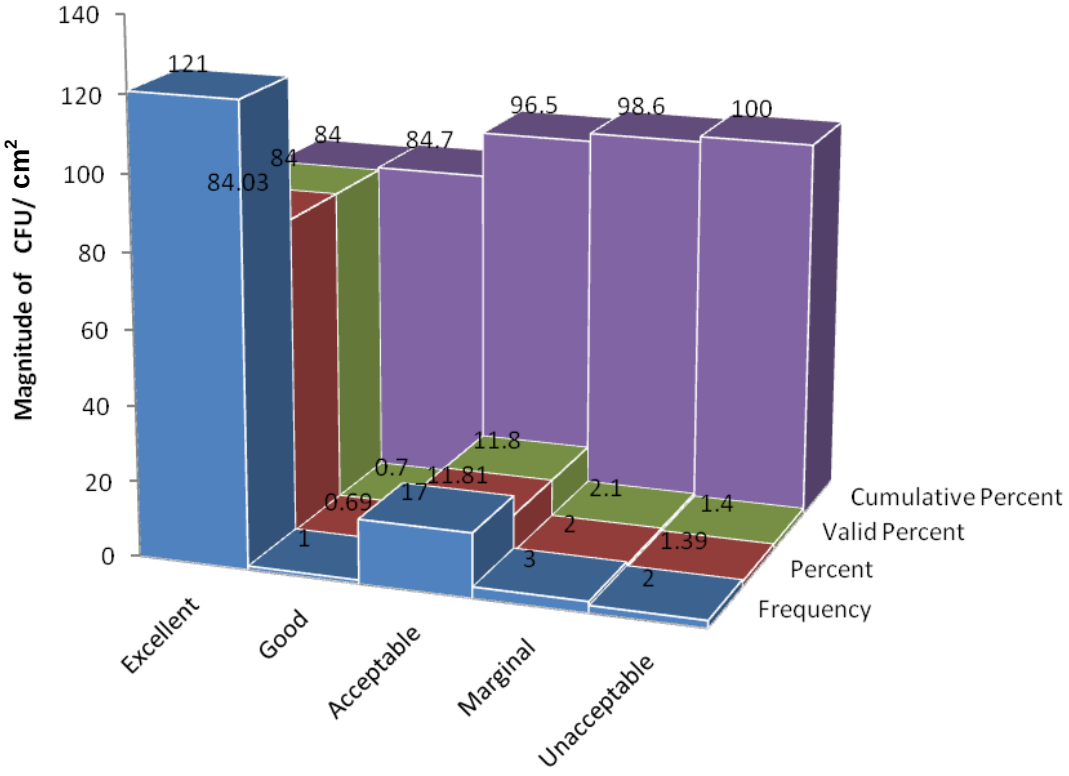


Figure 8. Frequency of CFU/cm^2 category distribution.

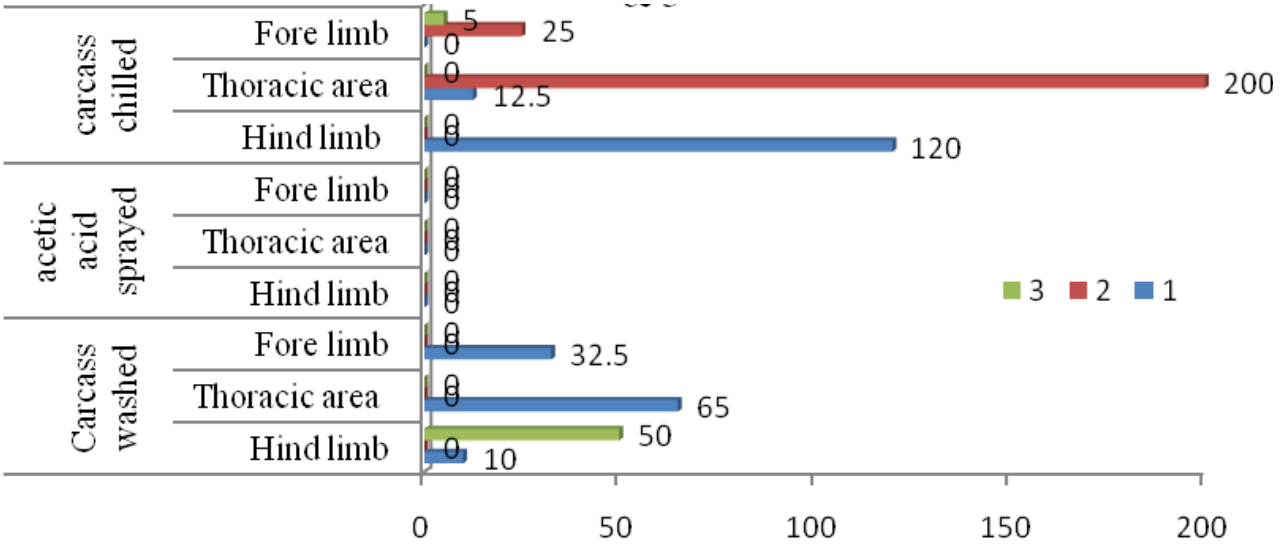


Figure 9. *E. coli* counts/cm^2 distribution in category in the swapped part of goat carcass in the sequential meat processing.

marginal. Marginal score resulted in acetic acid sprayed and chilled hind limb at the 1st sampling day, and 2nd sampling day, washed fore limb and thorax, and employee's apron from clean area of abattoir 1; simultaneously employee's palm from clean area of abattoir 2, and in the washed hind limb of abattoir 3 at the

3rd sampling day, that is not acceptable on fresh meat, indicating precautionary measures of meat hygiene along the slaughter and meat handling chains.

E. coli counts/cm^2 in abattoir 2 scored 200 in the thorax post acetic acid sprayed and chilling followed by abattoir 1 of apron in the clean area that scored 175 *E. coli*/cm^2. Thorax post acetic acid spray and chilling more contaminated by *E. coli* in abattoir 2 thorax followed by hind limb post washing was more contaminated by TPC log/cm^2 in abattoir 1.

The rate of carcass contamination was related to the higher contact area by the abattoir employee engaged to move manually goat or beef carcass conveniently by Ahouandjnou et al. (2015). However, Ahouandjnou et al. (2015) in Benin reported that there was 100% unsatisfactory (6.16±0.17) TPC log/cm^2 contamination in beef thigh while Zweifel and Stephen (2003) reported high contamination in neck and chest sites that contradict with the Ethiopian export abattoirs' goat carcass contamination mean findings of acceptable category (3.9±0.2 TPC log/cm^2), ranged 1.7 TPC log/cm^2 in abattoir 3 at the thoracic area after acetic acid spray to 7.4 TPC log/cm^2 at thorax after washing. There was no detection of CFU and *E. coli* in the carcass washing water, but significantly higher TPC log/cm^2, although it was categorically excellent distribution. Comparatively, in abattoir 1, there was higher bacterial contamination since both CFU and *E. coli* were in marginal category in employee apron working in clean area, followed by abattoir 2 where TPC log/cm^2 was marginal category that demands action for strict correction measures of HACCP implementation.

The bacterial loads decline from washing to acetic acid spray to chilling in the abattoirs in the carcasses' sampled parts, confirming that the sequential procedures do have vital effects in minimizing the bacterial counts, consistent to Bhandare et al. (2007, 2010) and FAO (2007). The research found meat contamination with significantly higher mean ($P< 0.05$) of 1.9±1 TPC/cm^2 and least in *E. coli*/cm^2 (1.28±0.8) that agreed with research findings of Haque et al. (2008) goat carcass report. On the basis of microbiological standards of raw meat, the finding of the microbial counts was indeed similar to Australian carcass standards that meat from well-controlled processes will usually be in the excellent or good categories, with only occasional departures into the acceptable category. It would be very unusual for these products to have TPC or *E. coli* count in the marginal category and other count is a trigger for investigating reasons for high counts, and for Corrective Action (AS4696-2002), consistent to this research findings of *E. coli* wise, 94.4% of the carcass was safe in cumulative of which 87.5% was excellent, 2.1% good, 4.9% acceptable and 5.6% marginal, 91% TPC of the carcass was safe in cumulative of which 46.5% was excellent, 25.7% good, 18.8% acceptable and 9% marginal. Coliforms wise, 96.5% of the carcass was safe in cumulative of which 84% was excellent, 0.7% good, 11.8% acceptable and 2.1% marginal. However, apron from clean area in abattoir 1 and thorax in chiller of abattoir 2 scored 1.39% unacceptable result, which alerts the HACCP team and the abattoirs' top management to strictly implement HACCP procedures for quality meat products routinely. Similar values to those presented in the study were confirmed by Jahan et al. (2015) whose findings stated 40% satisfactory and 32% acceptable for TPC, however, disagreed with 28% rejected resources which is the highest in comparative to our research. Martinez et al. (2010) has reported that most of the samples (63.7%) had TPCs of 4.1 to 5.0 CFU log/cm^2, and most of the carcasses (49.8%) had ECs of 1.1 to 2.5 CFU log/cm^2. According to the International Standard Organization (ISO 4833: 2003), TPC of 80% of analyzed samples must not exceed 5 log cfu/g, whereas 20% of the samples may have counts of up to 5 log cfu/g.

CFU strongly correlate with *E. coli* and weakly correlate with TPC. CFU significantly (0.01) correlate with *E. coli* and at 0.05 significance level with TPC. So strong correlation in between coliform and *E. coli* could have severe consequence in meat quality and risk in consumers' health. Haque et al. (2008) found a significant correlation between TPC and CFU that disagreed with the present research findings. The reduction of TPC after treatment in this study may be attributed to proper slaughtering procedures resulting in decreased level of contaminating bacteria (Aftab et al., 2012). However, there could be higher bacteria in chilling in abattoir 1 similar to research conducted by Abdalla et al. (2009) whose findings increased post washing. Jeffery et al. (2003) and Abdalla et al. (2009) found 3.74±0.02 log/cm^2 on workers' hands similar to our study findings of workers' hands and apron along with carcass washing water scored TPC log/cm^2 3.93±1.29 that was also supported by Jeffery et al. (2003) who confirmed workers' hands and equipments as sources of meat contaminations.

CONCLUSION AND RECOMMENDATION

The study was conducted to investigate the targeted organisms TPC, CFU and *E. coli* and were with safely acceptable range, but coliform result was unacceptable (1.39%) in abattoir 1 in employee apron in the 2nd visit day and abattoir 2 in the thorax post chilling in the 2nd visiting day that alerts the HACCP team although 96.5% of the carcass was safe cumulative wise of which 84% was excellent. The result confirmed that the bacterial loads decline from washing to acetic acid spray to chilling in three of the abattoirs' sampled carcass parts, confirming that the sequential procedures do have vital effects in minimizing the bacterial counts. Employee apron and thorax part of the carcass displayed bacterial

contamination to alert the abattoirs management. Carcass contaminating bacteria should be determined. Besides to the refreshing training need of abattoir employees, the abattoir supervisors could be source of contamination for they used to wander in and out restlessly with negligence of clean to dirty area routine procedures.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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