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Determination of Risk Factors and Prevalence of Salmonella in Slaughtered Small Ruminants and Abattoir Environment in an Export Abattoir, Modjo, Ethiopia

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Abstract: A survey study was conducted on 142 and 60 apparently healthy slaughtered sheep and goats, respectively, at an export abattoir, Modjo, Ethiopia from October 2007 to April 2008. The objectives were to determine prevalence of Salmonella in slaughtered sheep and goats and abattoir environment investigate the potential risk factors and Salmonella contamination rates of carcasses. A total of 1,240 samples consisting of skin swabs, eviscerator's hand swabs, eviscerating knife swabs, mesenteric lymph nodes, cecal contents, carcass swabs and water samples were collected. The samples were examined for the presence of Salmonella following standard techniques and procedures outlined by the International Organization for Standardization. From the total of 202 animals examined for Salmonella, 18 (8.9%) were positive, of which 11 (7.7%) were sheep and 7 (11.7%) were goats. In a total of 1,240 different samples, Salmonella was isolated in 89 (7.2%) samples of which 25 (12.4%) were carcass swabs, 11 (5.5%) mesenteric lymph nodes, 8 (4.0%) cecal contents, 10 (5.0%) skin swabs, 18 (8.9%) eviscerator's hand swabs, 15 (7.4%) eviscerating knife swabs and 2 (7.1%) water samples. Salmonellae were detected in all test samples obtained from sheep and goats. Although, no statistically significant results were observed except with eviscerating knife swab which was found to be significantly associated with carcass contamination. Sheep and goat carcasses that were eviscerated using Salmonella positive knives were 4.175 times more likely to be contaminated with Salmonella compared to those that were eviscerated with Salmonella negative knives. Therefore, proper sterilization of knives at 82°C should be implemented at abattoirs to reduce contamination of the meat and other edible offals during slaughtering operations.

INTRODUCTION

Food safety has been a concern of mankind since the dawn of history. Despite advances in food science and technology, foodborne diseases remain one of the major public health problems all over the world; they are also an important cause of reduced economic productivity (WHO., 1995; Legnani *et al*., 2003; Busani *et al*., 2005). The world Declaration on Nutrition, adopted by the FAO/WHO International Conference on Nutrition, emphasizes that hundreds of millions of people suffer from communicable and non-communicable diseases caused by contaminated food and water (WHO., 1995; Unnevehr and Jensen, 1998; Busani *et al*., 2005).

Food animals harbor a wide range of Salmonella serotypes and so, act as sources of contamination which is of paramount epidemiological importance in non-typhoid human salmonellosis. The process of removing the gastrointestinal tract during slaughtering of food animals is regarded as one of the most important sources of carcass and organ contamination with Salmonella at abattoirs. Moreover, contamination of meat by Salmonella may occur at abattoirs from the excretion of symptomless animals, contaminated abattoir equipment, floors and personnel and the pathogen can gain access to meat at any stage during butchering. Cross contamination of carcasses and meat products could continue during subsequent handling, processing, preparation and distribution (Hjartardottir *et al*., 2002; Molla *et al*., 2003; Vieira-Pinto *et al*., 2005; Woldemariam *et al*., 2005).

A number of studies conducted on poultry, pig, cattle, poultry meat, minced beef and humans in Ethiopia showed that salmonellae are prevalent in various food animals and meat products (Pegram *et al*., 2005; Nyeleti *et al*., 2000; Molla *et al*., 2003; Molla and Mesfin 2003; Ejeta *et al*., 2004; Woldemariam *et al*., 2005; Aragaw *et al*., 2007) and humans (Mache *et al*., 1997; Mache, 2002). Although, little study has so far been undertaken to determine the prevalence of Salmonella in sheep and goats in Ethiopia (Wassie 2004; Woldemariam *et al*., 2005), studies carried out elsewhere indicated that salmonellae are widespread in small ruminants (Sojka *et al*., 2009; Nabbut and Al-Nakhli, 2016; Chandra *et al*., 2007). Moreover, none of the previous studies in Ethiopia on small ruminant determined the occurrence, magnitude and distribution of Salmonella in the environment where sheep and goats are slaughtered. Therefore, this study was undertaken at a Modern export abattoir in Modjo with the objectives of establish the occurrence and prevalence of Salmonella in slaughtered sheep and goats and investigate the major sources of carcass contamination in abattoirs.

MATERIALS AND METHODS

Description of the study site and study population

Study site: The study was conducted in an export abattoir at Modjo, Ethiopia. Modjo town is the center of Lume District in Eastern Showa administrative zone, Oromia Regional State with an altitude of 1,777 m above sea level. It experiences a bimodal pattern of rainfall with the main rainy season extending from June to September and a short rainy season that extends from March to May with an average annual rainfall of 800 mm. The average maximum and minimum temperatures are 28 and 18°C, respectively (ILRI., 2005).

In the abattoir 200-600 sheep are slaughtered every Thursday and Sunday and 500-1,500 goats every day based on the demand from importers. Unscheduled slaughters which include small group of camels, cattle and calves, are also conducted up on the demand from their customers. Sheep and goats are slaughtered separately one after the other and the same personnel are involved in slaughtering both groups of animals. The slaughtering process involves bleeding using “Halal” method followed by hanging and washing the skin with tap water, flaying, evisceration, carcass washing with pressurized water and wiping with cloths. Personnel hands and carcass washing was done using tap water.

Study population: The study was carried out on apparently healthy slaughtered sheep and goats, apparently healthy abattoir personnel and the abattoir environment. The sheep and goats slaughtered at the abattoir were male and adult animals originated from different parts of the country mainly from Borana, Awash-Metehara, Bati Wolo, Babile and Ginir. The animals were transported on double-decked trucks. After arriving at the abattoir, the animals were rested for 24-72 h in concrete floored and roofed shades till they were slaughtered.

Study design and sampling: A survey study was undertaken on apparently healthy slaughtered sheep and goats, apparently healthy abattoir personnel and the abattoir environment at an export abattoir from October 2007 to April 2008. The variable of interest considered as an output variable at the slaughterhouse was carcass Salmonella status. The explanatory variables considered were Salmonella status of sheep and goat’s skin, eviscerating knives, eviscerator's hands, mesenteric lymph nodes, caecal contents and the water used to wash the carcass.

The sample size required for this study was determined depending on the expected prevalence of Salmonella and the desired absolute precision according to Thrusfield (2005). Previous study on Salmonella in sheep and goats in Modjo Export Abattoir recorded a prevalence of 10.3 and 3.9%, respectively (Wassie, 2004). Therefore, 95% confidence interval, 5% precision and respective 10.3 and 3.9% expected prevalence of sheep and goats were used to estimate the sample size.

Accordingly, the number of slaughter sheep and goats needed to demonstrate the prevalence of Salmonella was estimated at 142 and 60, respectively.

Sampling procedure: Individual animals were systematically sampled depending on the number of animals slaughtered on each day. Samples were collected weekly and on each visit 7 animals and equal numbers of environmental samples were collected.

From each selected slaughtered sheep and goats, skin swabs, mesenteric lymph nodes, cecal contents and carcass swabs were collected in separate sterile containers. Samples were also collected from eviscerating knives, eviscerator's hand and water used to wash the carcass. Selected animals were identified using two similar numbers attached by safety pin on the hind leg. One of these numbers was transferred to the eviscerated abdominal organs to match them with the carcasses.

Skin swabs were taken before bleeding was done. A swab moistened with 10 mL Buffered Peptone Eater (BPW) (AES loboratoire, Cedex, France) was used to rub the external skin where slaughtering incision was made and over the skin where incisions were made for flaying. Knives used for evisceration were sampled before each animal was eviscerated. The knife blade was twice swabbed from the tip to the base using sterile cotton wool moistened with 10 mL BPW (Botteldoorn *et al*., 2003).

Abdominal contents were removed to the gut room and sampled. About 25 g of mesenteric lymph node samples were collected in sterile universal bottles (Vieira Pinto *et al*., 2005). After disinfection with an alcohol-impregnated wipe, the cecal wall was incised using a sterile disposable scalpel and approximately 50 g of the content were also collected aseptically (McDowell *et al*., 2007).

Carcass swabs were collected at the end of slaughtering process according to Botteldoorn *et al.* (2003). The swab sampling was performed according to the protocol described by Bhandare *et al.* (2007) and ISO 17604 (2003).

Swabs from eviscerator's hands were taken immediately before the animal identified for sampling was eviscerated. Both hands were swabbed using a swab moistened with 10 mL BPW. In addition, water sample of 25 mL was also collected aseptically on every visit to the abattoir.

During sample collection, each sample was legibly and clearly labeled with identifying information which included date of sampling, type of sample and species of the animal from which the sample was obtained. The samples were then transported on ice to the Addis Ababa University, Faculty of Veterinary Medicine microbiology laboratory, Debre Zeit, Ethiopia, for processing and analysis upon arrival.

Isolation and identification of *Salmonella:* *Salmonella* was isolated and identified according to the techniques outlined in the International Organization for Standardization (ISO 6579 2002, 2004). The bacteriological media used in different stages of the isolation and identification of Salmonella were prepared according to the manufacturer's recommendations. All samples were processed separately.

Pre-enrichment in non selective liquid medium: All the samples were processed separately and then the processed samples in appropriate amount of BPW (1:9) were incubated for 18±2 h at 37±°C.

Enrichment in selective liquid media: Rappaport Vassiliadis with Soya (RVS) broth (Titan Biotech Ltd., Bhiwadi india) and Muller-Kauffmann tetrathionate with novobiocin (MKTTn) broth (Oxoid Ltd., Basingstoke Hampshire, England) were used for selective enrichment of all the samples except the cecal contents (ISO 6579 2002, 2004). In the case of cecal content samples modified semi-solid Rappaport-Vassiliadis (MSRV) medium (Bacto®, Difco Laboratories, USA) and MKTTn broths were used (ISO 6579:2002, 2004).

A 0.1 mL pre-enriched sample was transferred aseptically into a tube containing 10 ml of MSRV medium for cecal content samples or 10 mL of RVS broth for the remaining sample types and incubated at 41.5±1°C for 24±3 h. Another 1 mL of the culture obtained in pre-enrichment broth was transferred aseptically into a tube containing 10 ml of MKTTn broth and incubated at 37±1°C for 24±3 h.

Plating out and identification: Xylose Lysine Desoxycholate (XLD) agar (Titan Biotech Ltd., Bhiwadi india) and *Salmonella-Shigella* (SS) agar (Titan Biotech Ltd., Bhiwadi india) plates were used for plating out and identification purpose.

A loopfull of inoculum from each RVS, MSRV and MKTTn broth cultures was streaked onto XLD and SS agar plates and the inoculated plates were incubated at 37°C for 24±3h. After proper incubation, the plates were examined for the presence of typical Salmonella colonies. Typical colonies of Salmonella grown on XLD medium produce hydrogen sulphide and have a black (H_2S) center and a lightly transparent zone of reddish colour due to the colour change of the indicator ISO 6579 (2004) while on SS medium they become colorless colonies with black center. Salmonella H_2S negative variants (e.g., *S. paratyphi A*) grown on XLD agar are pink with a darker pink center whereas lactose-positive salmonellae are yellow with or without blackening.

Confirmation: For confirmation, at least five presumptive Salmonella colonies were selected from

every selective plating media. Whenever the suspected colonies on each plate were fewer than five, all the colonies were selected. The selected colonies were streaked onto the surface of pre-dried nutrient agar (Oxoid Ltd., Basingstoke Hampshire, England) plates in a manner that allow well-isolated colonies to develop and incubated at 37±1°C for 24±3h. Then, the pure cultures on nutrient agar were used for biochemical and serological confirmation (ISO 6579 2002, 2004).

Biochemical confirmation: Colonies suspected to contain Salmonella were tested biochemically according to the recommendations of ISO 6579 (2002, 2004). The biochemical tests included glucose, lactose and sucrose fermentation and gas and H_2S production in TSI agar, growth in L-lysine decarboxylation medium, urease, Voges-Proskauer (VP) and Indole production tests.

TSI (Oxoid Ltd., Basingstoke Hampshire, England) and Lysine Iron Agar (LIA) (Difco™, Becton Dickinson, Claix, France) slants were inoculated by stabbing the butt and streaking the slant. In addition, pure colonies were inoculated onto urea (Oxoid Ltd., Basingstoke Hampshire, England) broth, methyl red-Voges-Proskauer (Titan Biotech Ltd., Bhiwadi india) medium and SIM (BBL®, Becton Dickinson and Company Cockeysville, USA) medium for further characterization. For comparison purposes and ease of identification on plates, presumptive Salmonella colonies were also inoculated onto Rambach™ agar (CHROMagar, Paris France) plates. The inoculated media were then incubated at 37°C for 24±2 h according to the recommendations of ISO 6579 (2002, 2004).

Data management and analysis: All data were entered into a Microsoft Excel spreadsheet and checked for accuracy. After validation, data were transferred to SPSS release 11.5.0 for analyses.

Species-and-sample-specific prevalences of Salmonella were expressed as percentages. The prevalence was defined as the number of Salmonella positives per the number of samples examined. An animal was considered positive when a mesenteric lymph node and/or cecal content sample were culture positive for Salmonella. The agreement of the mesenteric lymph node and cecal content results was measured using the Kappa statistic. The data were analysed by comparing proportions using Pearson's chi-square or Fisher's exact test based on the number of observations per contingency table cells.

For association of risk factors considered in the abattoir with carcass contamination, multiple stepwise logistic regression analysis was used. The explanatory variables considered (skin swab, eviscerating knife swab, eviscerator's hand swab, cecal content, mesenteric lymph node and water sample Salmonella status and total slaughter volume) were separately analysed to see their associations with the outcome of the bacteriological status of the carcass.

RESULTS

The present study was conducted on 142 and 60 apparently healthy slaughtered sheep and goats respectively at an export abattoir, Modjo, Ethiopia from October 2007 to April 2008 with the objectives of establishing prevalence of Salmonella in slaughtered sheep and goats, determining serotype diversity in slaughtered sheep, goats and abattoir environment, providing information as to the major sources of carcass contamination in abattoirs and forward strategies to minimize the contamination. Bacteriological examination was conducted on Skin Swab (SkS), eviscerating Knife Swab (KS), eviserator's Hand Swab (HS), Cecal Content (CC), Mesenteric Lymph Node (MLN), Carcass Swab (CS) (each n = 202) and 28 Water (WS) Samples.

Prevalence of *Salmonella:* Out of the total 202 animals (142 sheep and 60 goats) examined for bacteriological status of Salmonella, 18 (8.9%) were positive of these, 11 (7.7%) were sheep and 7 (11.7%) were goats. No statistically significant differences ($p>0.05$) were found between sheep and goats in being positive for Salmonella (Table 1). An animal was considered Salmonella positive when it was bacteriologically positive either for MLN and/or CC. Skin and carcass Salmonella statuses were considered indicators of contamination and were not used for the calculation of prevalence. Of the 18 positive animals, only 1 (5.6%) animal was culture positive both for MLN and CC samples. The rest (94.6%) were culture positive either for MLN or for CC samples and were not significantly different ($p = 0.366$). The agreement of the MLN and CC samples was measured using the Kappa statistics and the result indicated low agreement between the two (Kappa value = 0.062, 95% CI = -0.074-0.198).

Of the total 1240 samples examined from sheep, goats, abattoir personnel and abattoir environment, Salmonella was isolated in 89 (7.2%) samples of which 25 (12.4%) carcass swab, 11 (5.5%) mesenteric lymph node, 8 (4.0%) cecal content, 10 (5.0%) skin swab, 18 (8.9%) eviserator's hand swab, 15 (7.4%) eviscerating knife swab and 2 (7.1%) water samples were positive for Salmonella (Table 2).

Table 1: Comparative results of species-specific Salmonella prevalence in MLN and CC samples at Modjo Export abattoir, Ethiopia

Sample types	Odds ratio	CI for the odds ratio	p-values
MLN	1.134	0.290-4.431	0.579
CC	0.237	0.055-1.027	0.052

MLN = Mesenteric Lymph Node, CC = Cecal Content, CI = Confidence Interval

Table 2: Prevalence of *Salmonella* by sample types and species of animals examined

Sample types	Number of samples								
	Sheep			Goats			Total		
	Examined	Positive (%)	95% CI	Examined	Positive (%)	95% CI	Examined	Positive (%)	95% CI
SkS	142	7 (4.9)	2.2-10.3	60	3 (5.0)	1.3-14.8	202	10 (5.0)	2.5-9.2
MLN	142	8 (5.6)	2.6-11.2	60	3 (5.0)	1.3-14.8	202	11 (5.5)	2.9-9.8
CC	142	3 (2.1)	0.6-6.5	60	5 (8.3)	3.1-19.1	202	8 (4.0)	1.9-7.9
CS	142	20 (14.1)	9.0-21.2	60	5 (8.3)	3.1-19.1	202	25 (12.4)	8.3-17.9
HS*	142	15 (10.6)	6.2-17.1	60	3 (5.0)	1.3-14.8	202	18 (8.9)	5.5-13.9
KS*	142	12 (8.5)	4.6-14.6	60	3 (5.0)	1.3-14.8	202	15 (7.4)	4.4-12.2
WS*	20	1 (5.0)	0.3-26.9	8	1(12.5)	0.7-53.3	28	2 (7.1)	1.3-25.0
Overall	Positive = 11(7.75%)			Positive = 7(11.7%)			Positive = 18(8.9%)		

SkS = Skin Swab, MLN = Mesenteric Lymph Node, CC = Cecal Content, CS = Carcass Swab, HS = eviscerator's Hand Swab, KS = eviscerating Knife Swab, WS = Water Sample and CI = Confidence Interval *Sample types collected during sampling of the respective species of animals

Table 3: Summary results of multiple stepwise logistic regression of the associations of carcass contamination with *Salmonella* with the risk factors

Risk factors	Coefficient	SD	p-values	Odds ratio	95% CI for the odds ratio
SkS	0.608	0.821	0.459	1.837	0.367-9.186
MLN	1.058	0.714	0.138	2.881	0.711-11.673
CC	0.908	0.846	0.283	2.478	0.472-13.014
HS	0.796	0.613	0.193	2.218	0.668-7.367
KS	1.429	0.597	0.017	4.175	1.297-13.444
WS	2.037	1.542	0.186	7.667	0.374-157.361
Total slaughter volume	0.000	0.001	0.576	1.000	0.999-1.001

SD = SE, CI = Confidence Interval, SkS = Skin Swab, MLN = Mesenteric Lymph Node, CC = Cecal Content, HS = eviscerator's Hand Swab, KS = eviscerating Knife Swab and WS = Water Samples

Salmonellae were detected in all test samples obtained from sheep and goats with different frequencies of occurrence. There were no statistically significant differences ($p>0.05$) in the proportions of Salmonella between sheep and goat samples.

The level of carcass contamination was considered as an outcome variable taking skin swab, mesenteric lymph node, cecal content, eviscerator's hand swab, eviscerating knife swab and water sample Salmonella status and total slaughter volume as risk factors for carcass contamination. Therefore, associations of carcass contamination with the risk factors were assessed using logistic regression analysis (Table 3) and no statistically significant associations could be demonstrated between the carcass contamination and skin swab, mesenteric lymph node, cecal content, eviscerator's hand swab, water sample Salmonella status and total slaughter volume ($p>0.05$). However, eviscerating knife swab was found to be significantly associated ($p = 0.017$) with carcass contamination and the Odds Ratio (OR) was 4.175. Therefore, carcasses of animals that were eviscerated using Salmonella positive knives were 4.175 times (OR = 4.175, 95% CI = 1.297-13.444) more likely to be contaminated with Salmonella compared to those that were eviscerated using Salmonella negative knives. But the biological significance of some potential risks showed high probability of associations for example, MLN with OR = 2.88, CC with OR = 2.48, HS with OR = 2.22 and WS with OR = 7.67.

DISCUSSION

In the present study, the prevalence of Salmonella in apparently healthy slaughtered sheep and goats was 7.7 and 11.7%, respectively. These findings are in agreement with the report of D'Aoust (1989) which indicated that prevalence of Salmonella ranged between 2 and 51.5% in sheep and 1-18.8% in goats. Woldemariam *et al*. (2005) reported respective prevalence of 2.8 and 9.8% in apparently healthy slaughtered sheep and goats in Debre Zeit, Ethiopia. Similarly, a study undertaken in slaughtered sheep and goats in Hyderabad indicated a higher prevalence (6%) of salmonellosis in goats as compared to the sheep (1.64%) (Rajmalliah *et al*., 1989). In contrast, Wassie (2004) found a high prevalence of Salmonella in sheep of 11.5% as compared to goats of 3%. The current study revealed results which are slightly lower than the respective 14.7 and 18.3% prevalence in slaughtered sheep and goats in Riyadh Public Abattoir, Saudi Arabia (Nabbut and Al-Nakhli, 2016) and the 17.6% prevalence of *Salmonella* in goats slaughtered for chevon in India (Chandra *et al*., 2006).

The difference in the reported prevalences could be associated with the sampling plan and procedures, sample type, the bacteriological techniques employed in detecting Salmonella or difference in occurrence and distribution of Salmonella in the study population regardless of test samples and methods of detection. It is also known that keeping animals to be slaughtered in crowded waiting pens at abattoirs could facilitate the excretion and

transmission of infection among them. In addition to this, stress could induce higher infection rates among animals when they are held in the market for long periods before slaughter (Watson, 2010; Radostits *et al*., 1994).

The respective 2.1 and 8.3% *Salmonella* prevalence in cecal contents of sheep and goats obtained in this study compared well with the respective 2.1 and 3.3% prevalences of Salmonella in sheep and goat feces reported by Woldemariam *et al.* (2005) and the 4.8 and 2% fecal prevalence of sheep and goats respectively by Wassie (2004). However, a study carried out to estimate the prevalence of fecal Salmonella in healthy pigs, cattle and sheep at a slaughter in Great Britain yielded a Salmonella prevalence of 0.1% in cecal contents of sheep (Davies *et al*., 2004) which was slightly lower than the findings of the current study. It is well documented that, when animals are starved, salmonellae can survive and multiply in the rumen. Moreover, healthy carriers intermittently excrete only a few salmonellae, unless they undergo some kind of stress, for example during transportation or holding in the lairages prior to slaughter (Moo *et al*., 2008; Samuel *et al*., 2010; Nabbut and Al-Nakhli, 2016; Venter *et al*., 1994). Therefore, the present high cecal prevalence of *Salmonella* could be associated with the exposure of animals to such predisposing factors as starvation, overcrowding, transportation and longer lairage confinement prior to slaughtering.

The detection of Salmonella of 5.6 and 5.0% in the mesenteric lymph nodes of sheep and goats respectively, supports earlier observation by Moo *et al.* (2008) who reported a 4% Salmonella prevalence in mesenteric lymph nodes in Australian sheep. However, the current study findings considerably vary from other previous reports. Wassie (2004) reported 7.7 and 2% prevalence of Salmonella in the mesenteric lymph nodes of sheep and goats, respectively. Woldemariam *et al.* (2005) also found respective 0 and 11.7% prevalence of Salmonella in sheep and goat mesenteric lymph nodes. According to Nabbut and Al-Nakhli (2016), the enrichment method revealed more infected lymph nodes than by direct plating method. Therefore, the differences in the reported prevalence could be associated with the bacteriological techniques employed for the detection of Salmonella or differences due to the distribution of the organisms in different study populations in different prevailing conditions. In the present study, there was no statistical association between mesenteric lymph node Salmonella prevalence and carcass contamination. This could be due to the fact that lymph nodes are solid enclosed tissues so that they are not likely to contaminate hands of butchers, environment or carcasses, unless incised during inspection.

In this study, 7.1% (2/28) Salmonella prevalence was recorded in the water samples used to wash the carcasses. No comparable data is available for water used to wash sheep and goat carcasses. However, no Salmonella was recovered from 16 scalding water samples at Addis Ababa abattoir, Ethiopia (Aragaw *et al*., 2007) and in 5 Belgian slaughterhouses (Botteldoorn *et al*., 2003). Moreover, a study undertaken to determine the level of selected bacteria in the water used for the rinsing of broiler carcasses at small retail processing operations in Trinidad resulted with 5.1% (4/78) Salmonella prevalence (Rodrigo *et al*., 2005). Another study of sensitivity and description of Salmonella isolated from poultry slaughterhouses and workers in Iraqi revealed 20 and 5% prevalence of Salmonella from washing and scalding water, respectively (Sultan and Sharif, 2002). The absence of Salmonella in scalding water seems to be due to high scalding water temperature recorded during slaughter activities. But in this Modjo abattoir survey cold water was used to wash the carcasses of sheep and goats which may have contributed to the relative high prevalence of Salmonella in it.

A 7.4% Salmonella prevalence from the eviscerating knives obtained in this study was in consistent with the 5% prevalence of evisceration knife-study in Queensland, Australia (Peel and Simmons, 2008) and the 5% prevalence on the killing knives in poultry slaughterhouses in Iraqi (Sultan and Sharif, 2002). Another study on knife blades undertaken to indicate the prevalence of Salmonella reported 26.7 and 10% prevalence at two Botswana abattoirs, A and B, respectively (Motsoela *et al*., 2016).

A study was undertaken to examine salmonellae on posts, handrails and hands in a beef abattoir in Queensland. Salmonellae were isolated from the hands of workers in all stages along the slaughtering line particularly 30% on the hands of workers in the evisceration area (Smeltzer *et al*., 2008b). Comparatively, that prevalence was higher than the 8.9% recorded in Modjo abattoir study. Watson (2010) described that washing of the hands with soap and running water for 15 sec is needed to remove an inoculum of 100 or less of Salmonella organisms from the finger tips. While, heavier inocula leave viable salmonellae on the hands even after such washing. Similarly, Smeltzer *et al.* (2008a) indicated that washing is an essential part of any program aimed at reducing cross contamination of carcasses with Salmonella. Therefore, the low prevalence obtained in this study could be as a result of frequent hand washing which might have reduced bacterial loads from the hands of those personnel to low levels.

It is clear that the presence of Salmonella excretors in batches of animals in transit and passing through the lairage could result in contamination of skins. Moreover, Bacon *et al.* (2016) indicated that external surfaces of animals serve as a source of contamination for the underlying, sterile carcass surfaces during the dehiding process. Examination of 100 cattle and 100 sheep passing

through 10 abattoirs in Australia showed a high level of Salmonella contamination of the hides in cattle (57%) and fleece in sheep (51%) (Watson, 2010). This finding is much higher than the findings of 4.9 and 5% *Salmonella* prevalence obtained from the skin of sheep and goats, respectively in this study. However, no statistically significant association was found between skin swab *Salmonella* prevalence and carcass contamination. The probable reason for this is that there was less contact between the skin and the underlying, sterile carcass surfaces as flaying in the study abattoir was carried out automatically. It has been indicated that manual operation of all the processing steps during slaughtering of the animals in abattoirs, rather than the use of semi-automatic or automatic systems in operations increases the probabilities of contamination of edible organs and spreading of salmonellae in abattoir environments (Nabbut and Al-Nakhli, 2016).

This study recorded 14.1% prevalence of Salmonella on sheep carcasses and 8.3% on goats. These are in consistent with reports of previous works. Woldemariam *et al.* (2005) reported respective 7.4 and 7.5% prevalence of *Salmonella* on carcasses of sheep and goats at Debre Zeit abattoir, Ethiopia and Sierra *et al.* (2016) reported 10% prevalence of Salmonella on freshly dressed lamb carcasses in Spain. On the other hand, microbiological quality survey on sheep carcasses obtained 1.5 and 0.1% prevalence of Salmonella in USA and Australia respectively which are lower than the current findings (Duffy *et al*., 2016; Phillips *et al*., 2016). The high level of carcass contamination with *Salmonella* is of special public health significance for a country like Ethiopia where raw and undercooked meat is the favorite meal in most areas.

The surfaces of carcasses are easily contaminated with salmonellae in abattoirs with poor hygienic control during skinning and evisceration from symptomless animal excretors, contaminated abattoir equipment and floors. Furthermore, it has been reported that slaughtering practices such as poor disinfections of knives and other equipment, slaughter floor drains, poor personal hygiene of slaughterhouse personnel and poor sanitation of slaughterhouse are important in the contamination of carcasses (Nabbut and Al-Nakhli, 2016; Adesiyun and Oni, 1989; Sierra *et al.* 2016).

In the present study, the level of carcass contamination was considered as an outcome variable taking mesenteric lymph node, cecal content, skin swab, eviscerator's hand swab, eviscerating knife swab and water sample Salmonella status and total slaughter volume as risk factors for carcass contamination. Although the associations of carcass contamination with the potential risk factors was assessed, no statistically significant associations could be demonstrated between the carcass contamination and the risk factors except with eviscerating knife swab which was found to be significantly associated with carcass contamination. However, there were other risk factors which showed significant (OR>1) associations with contamination of carcasses. Nevertheless, specific attention must be given to the sterilization of knives. As clearly indicated by different workers (Watson, 2010; Smeltzer *et al.*, 2008a; Motsoela *et al.*, 2016), it is salutary to note that knives must be immersed in water for 2 minutes at 82°C to reduce the number of contaminating microorganisms. In line with this, although sterilization of the knives by immersion in water at 82°C for at least 10 sec may significantly reduce the number of Salmonella on knives, subsequent contacts with either the steel or scabbard may serve to apply a fresh inoculum. Therefore, provision should be made for regular sterilization of both steels and scabbards and the knives.

As indicated by Norval (1961), there is no doubt that the wiping cloths used by slaughter personnel for cleaning up the carcasses could be an important source of contamination of carcasses. In this survey it was observed that after washing the carcasses using pressurized water, slaughter personnel used wiping cloths to clean and dry the surface of the carcasses. Moreover, the wiping cloths used were not sterile and one wiping cloth was used for a number of continuous carcasses. This situation might considerably contribute to the cross contamination of carcasses resulting in relatively high prevalence of Salmonella on carcasses. In certain foreign countries, wiping cloths have been prohibited.

According to Smeltzer *et al.* (20080a), contacts between aprons and the carcasses are unavoidable in many locations and may result in carcass-to-carcass transfer of Salmonella. In addition, results from different studies showed that equipment that indirectly or accidentally contacts the carcass such as steels, scabbards, aprons, protective rails, stainless steel sheets or other fixed structures does contribute to the spread of Salmonella in a meat works. All these factors may also contribute to the relatively higher prevalence of Salmonella on carcasses of the slaughtered sheep and goats obtained in this study. Therefore, this role would need to be considered if attempts to reduce Salmonella contamination of the carcass by sanitizing other equipment, knives, saws, cutting boards etc. were to be successful. Furthermore, Adesiyun and Oni (1989) emphasized that meat from the following day's slaughter could therefore be contaminated with salmonellae from animals slaughtered the previous day.

CONCLUSION

In conclusion in the present study Salmonella were detected in sheep and goats from skin, mesenteric lymph

nodes, cecal contents, carcasses and also on the abattoir personnel hands, eviscerating knives and water samples with different frequencies of occurrence. There was high contamination of sheep and goats carcasses with Salmonella indicating the role of slaughter processes followed by the abattoir in carcass contamination. Eviscerating knife was found to be the main source of carcass contamination during the slaughtering process.

Carcasses of sheep and goats that were eviscerated using Salmonella positive knives were more likely to be contaminated with this microorganism compared to those that were eviscerated using Salmonella negative knives. Therefore, good hygienic practices in the abattoir and applications of the hazard analysis critical control point concept should be put in place in order to eliminate or reduce foodborne pathogens to acceptable limits including Salmonella.

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