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Original Article

Salmonella serovars along two beef chains in Ethiopia

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Abstract

Introduction: *Salmonella* has been reported from foods and the food production environment, with outbreaks occurring in the human population worldwide.

Methodology: A survey on *Salmonella* in two beef production lines (a beef abattoir line and a processing line) in Addis Ababa, Ethiopia was conducted, with a total of 668 various samples randomly collected from animal-related materials, the environment, and a beef product (mortadella).

Results: Overall, a 12.9% prevalence (26.3% from the abattoir line, 5.3% from the processing plant line) was observed. The prevalence in the abattoir line environment (36.6%) was higher than that in animal-related samples (14.7%); the reverse was true for the processing plant line. Out of 86 isolates, 10 serovars were identified, and 8 remained unidentified. The predominant serotypes were *S.* Saintpaul (32.5%), *S.* Muenchen (19.8%), and *S.* Larochelle (12.8%). *S.* Kastrup and *S.* London were isolated for the first time in Ethiopia.

Conclusions: Data indicate open ports of entry for *Salmonella*, with possible transfer along the line. Further investigations from farm to fork are recommended in order to identify these positions of entry.

Key words: *Salmonella* serotypes; beef; processing plant; abattoir; food chains.

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Introduction

In Ethiopia, consumption of raw meat is traditional, which carries the risk of foodborne infections and intoxications [1]. Several studies on *Salmonella* prevalence in Ethiopia have been published (*e.g.*, among cattle, slaughterhouse personnel, the environment, and minced beef) [1-3].

Salmonella has been reported from foods and the food production environment, with outbreaks occurring in the human population worldwide. Kagambega *et al.* [4] reported *Salmonella* data in cattle from Burkina Faso, and Adabara *et al.* [5] from hospital cases in Nigeria. *Salmonella* reports are available in Ethiopia on the prevalence of *Salmonella* in different food animals, such as cattle, sheep, goats and pigs [1,2,6-8], camels [9], chickens [10] at abattoirs, from animal products at supermarkets [1,2,11], and from human cases [12,13]. Serotypes reported from Ethiopia include 48% each for *S.* Dublin and *S.* Mishmarhaemek, 20% for *S.* Typhimurium [8], 54% for *S.* Anatum, 19% for *S.* Newport [3], 38.8% for *S.* Saintpaul, and 22.4% for *S.* Braenderup [9]. *S.* Haifa, *S.* Infantis, *S.* Enteritidis, *S.* Braenderup, and *S.* Muenchen were also frequently isolated from animal and food of animal origin in abattoirs and supermarkets [1-3,8-11,14-15]. *S.* Concord was obtained from hospital case samples [16]. Unidentified *Salmonella* strains were also reported from food of animal origin [14,15] and from humans [17].

Previous studies in Ethiopia did not follow structured sampling plans along beef production chains. This survey intended to identify possible sources for transfer of *Salmonella* serovars along two beef chains in Ethiopia.

Methodology

Ethical considerations

This project was approved and funded by the Ethiopian Engineering Capacity Building Program (ECBP) offices of Ethiopia.

Abattoir and processing lines

A cross-sectional study was carried out along two lines: a cattle abattoir line and a beef processing plant

line. In the abattoir line, multi-purpose cattle stocks purchased from extensive or semi-intensive management systems in different parts of the country, either tracked or trucked, are slaughtered at Addis Ababa Abattoir Enterprise (AAAE) [17]. The AAAE has a capacity of up to 1,200 cattle in 8 hours with a staff of about 700 persons. After slaughter, carcasses are delivered to city butcheries, immediately or after a short cooling interval. Butcheries are mostly small open-stall shops, handling the meat at 20°C–27°C, which is the ambient temperature in Addis Ababa City.

The processing plant line is located at Bishoftu town, 47 km east of Addis Ababa. It receives raw beef from three abattoirs, (from AAAE in Addis Ababa, from Adama Municipal Abattoirs in Adama [located 90 km east of Addis Ababa] and from Bishoftu Municipal Abattoirs in Bishoftu). In this small-scale plant (8 to 10 working persons), beef is processed in a working area without intersections either immediately or is kept in a refrigerator until processing. The product (beef mortadella) goes to private supermarkets in Addis Ababa City. Here, products are kept in the refrigerator with other products of animal origin. Slicing is done using one slicing machine for all products during supply to the consumers.

Sampling

Samples were taken from December 2011 to April 2012 over 18 sampling occasions: 5 times from the abattoir and butchery, and 13 times from the beef processing plant line, 8 times from the processing plant, and 5 times from supermarkets.

In the abattoir, samples were taken from the operation environment, directly from the animal/product, and raw beef from city butchery locations. In the processing plant line, samples were taken from the environment, from animal products, and from supermarkets in Addis Ababa.

From both lines, 668 samples from a total of 35 sampling locations were taken (Table 1). For swabs, a 50 cm^2 area was swabbed with sterilized gauze moistened with normal saline solution. Water (20 mL) was filled directly from the tap into sterile calibrated glass bottles. Tissue and product samples were taken aseptically and placed in sterile stomacher bags. Samples were immediately transported to Microbiology Laboratory, Akililu Lemma Institute of Pathobiology, Addis Ababa University (ALIPB-AAU), Ethiopia on the day of sampling using an ice box at +4°C.

Sample preparation

Each sample was aseptically taken. For pre-enrichment, buffered peptone water (Merck, Darmstadt, Germany) was used. The first 1:10 dilution was homogenized with a Stomacher 400 (Seward Laboratory, London, UK) and incubated at 37°C for 18–20 hours to be used as pre-enrichment [18,19].

Salmonella isolation and serotyping

Next, 0.1 mL and 1 mL, respectively, of the 1:10 pre-enrichment were transferred to 10 mL each of Rappaport-Vassiliadis (RV) medium (Oxoid Ltd., Basingstoke, UK) and Muller-Kauffmann tetrathionate novobiocin (MKTTn) (Oxoid Ltd., Basingstoke, UK) broth and incubated for 18–24 hours at 43°C and 37°C, respectively. Of both, a loopful was plated on brilliant-green phenol-red lactose-sucrose agar (BPLS) (Oxoid Ltd., Basingstoke, UK) and xylose lactose tergitol 4 agar (XLT4) (Merck, Darmstadt, Germany) and incubated at 37°C for 24 hours and 48 hours [20]. Suspected colonies were exposed to polyvalent-I and polyvalent-II sera (SIFIN, Berlin, Germany). For final serotyping, *Salmonella* O- and H-antisera (SIFIN, Berlin, Germany) were used.

Data analysis

Data were entered in to Microsoft Excel 2007 (Microsoft Corp., Redmond, USA) and analyzed using Excel, State 11, and SPSS version 20 (IBM Corp., Armonk, USA). Percentage and mid-prevalence exact 95% confidence intervals (CI) were used to demonstrate prevalence differences between and among the sampling occasions and types of samples.

Results

Prevalence

An overall *Salmonella* prevalence of 12.9% was obtained. The number of positive results in the abattoir line (26.3%; 95% CI: 21.2–32.5) was significantly higher than in the processing plant line (5.3%; 95% CI: 3.5–7.8) ($p < 0.05$).

Abattoir line

More positive results were obtained from environmental samples (36.6%; 95% CI: 27.6–46.4), than from animal-related samples (14.7%; 95% CI: 8.7–22.9). Prevalence at the butcheries (32.4%; 95% CI: 18.3–49.3) was similar to results from environment materials. No difference was observed between and among all sampling locations at the abattoir line ($p > 0.05$) (Table 2).

Processing plant line

Here, fewer positive results were obtained from environmental samples (5.2%; 95% CI: 2.6–8.9) than from animal-related samples (10.2%; 95% CI: 5.6–16.6). *Salmonella* was not recovered from aprons, knives, tap water, refrigerators, spices and weighing equipment, meat grinders, and mixers. Supermarkets yielded only 1 positive result (from 119 samples) (0.8%; 95% CI: 0.04–4.1) ($p > 0.05$) (Table 3).

Serovars

In total, 86 *Salmonella* strains were obtained and serotyped (Table 4). Of the 10 different serovars identified, 3 of them were found only in the abattoir line and 4 only in the processing plant line. A total of 3 serovars (*S.* Saintpaul, *S.* London, *S.* Muenchen) along with unidentified ones were isolated from both lines. Predominant serotypes were *S.* Saintpaul (32.5%), *S.* Muenchen (19.8%), and *S.* Larochelle (12.8%).

Table 1. Sampling locations, sample types, and number enrolled from both lines.

Line	Origin of sample		Processing stages/position	Sampling location	N
Abattoir line	Abattoir	Environment	Before stunning and beginning of operation	Personnel's hands	13
				Aprons	14
				Knives	13
				Tap water	12
				Hooks	11
			At carcass splitting	Rooms	17
			Refrigeration	Refrigerators	10
			Meat transport	Meat transport trucks	11
			Sub total		101
		ARM	Before stunning	Stunning	34
			During evisceration	Evisceration	34
			After washing when ready for distribution	Inspection	34
			Sub total		102
	Butchers		Butchers, 6-8 hours post delivery	Beef for consumption	34
	Total				237
Processing plant line	Processing plant	Environment	Manual production	Personnel's hands	19
				Aprons	16
				Knives	15
				Cutting plates	13
			Cleaning water	Tap water	17
				Working tables	17
			Device-related materials	Room floors	16
				Refrigerators	15
			Spicing	Spices	15
				SWE	15
			Beef processing electrical machinery	Grinder	9
				Cutter	9
				Mixer	9
				Filler/stuffer	9
			Sub total		194
		ARM	Raw beef incoming	Before processing	118
	Supermarkets		End product	Supermarket A	15
				Supermarket B	15
				Supermarket C	15
				Supermarket D	14
				Supermarket E	15
				Supermarket F	15
				Supermarket G	15
				Supermarket H	15
			Sub total		119
	Total				431
Grand total					**668**

ARM: animal-related materials; MLN: mesenteric lymph node; SWE: spice weighing equipment.

Table 2. *Salmonella* isolates by sampling location and type of samples (abattoir line).

Sample origin	Processing stage	Sampling location	Sample type	N samples	N (%) positive	Mid-pex 95% CI
Environment	Before stunning	Personnel's hands	Hand swabs	13	5 (38.5)	15.7–65.9
		Aprons	Apron swabs	14	5 (35.7)	14.4–62.4
		Knives	Knife swabs	13	4 (30.7)	10.6–58.7
		Tap water	Water sample	12	1 (8.3)	0.4–34.7
		Hooks	Hook swabs	11	2 (18.2)	3.2–48.3
	Carcass splitting	Floors	Room swabs	17	9 (52.9)	29.7–75.2
	Refrigeration	Refrigerator	Refrigerator swabs	10	6 (60.0)	29.1–85.8
	Meat transport	Transport truck	Truck swabs	11	5 (45.5)	18.9–74.1
	Sub total			101	37 (36.6)	27.1–46.4
ARM	Before stunning	Stunning	Animal feces	34	8 (23.5)	11.6–37.8
	During evisceration	Evisceration	MLN samples	34	3 (8.8)	2.3–22.2
	After washing, ready for transport	Inspection	Raw meat samples	34	4 (11.8)	3.8–25.9
	Sub total			102	15 (14.7)	8.8–22.6
Butchery (product)	Butcheries, 6–8 hours after delivery	Beef for consumption	Retail samples	34	11 (32.4)	18.3–49.3
Total				**237**	**63 (26.6)**	**21.3–32.5**

Mid-pex: mid-prevalence exact; ARM: animal-related materials; MLN: mesenteric lymph node.

Table 3. *Salmonella* isolates by sampling location and type of samples (processing line).

Sample origin	Processing stage	Sampling location	Sample type	N samples	N (%) positive	Mid-pex 95% CI
Environment	Manual production	Personnel's hands	Hand swab	19	1 (5.2)	0.3–23.3
		Aprons	Apron swab	16	0	0–17.1
		Knives	Knife swab	15	0	0–18.1
		Cutting plates	Plate swab	13	1 (7.7)	0.3–25.7
	Cleaning water	Tap water	Water sample	17	0	0–16.2
	Materials	Working tables	Table swabs	17	3 (17.7)	4.7–40.9
		Floors	Room swabs	16	3 (18.7)	5.0–43.0
		Refrigerator	Refrigerator swab	15	0	0–18.1
	Spices adding	Spices	Spice sample	15	0	0–18.1
		SWE	SWE swab	15	0	0–18.1
	Beef processing electrical machinery	Grinder	Grinder swab	9	0	0–28.3
		Cutter	Cutter swab	9	1 (11.1)	0.5–43.9
		Mixer	Mixer swab	9	0	0–28.3
		Filler/stuffer	Filler swab	9	1 (11.1)	0.5–43.9
	Sub total			194	10 (5.2)	2.6–8.9
ARM	Raw beef	Before processing	Raw meat samples	118	12 (10.2)	5.6–16.6
	Sub total			312	22 (7.1)	5.6–10.3
Supermarkets (product)	End product	Supermarket A	Mortadella	15	0	0–18.1
		Supermarket B	Mortadella	15	1 (6.7)	0.3–28.7
		Supermarket C	Mortadella	15	0	0–18.1
		Supermarket D	Mortadella	14	0	0–19.3
		Supermarket E	Mortadella	15	0	0–18.1
		Supermarket F	Mortadella	15	0	0–18.1
		Supermarket G	Mortadella	15	0	0–18.1
		Supermarket H	Mortadella	15	0	0–18.1
	Sub total			119	1 (0.8)	0.04–4.1
Total				**431**	**23 (5.3)**	**3.5–7.8**

SWE: spice weighing equipment; ARM: animal-related materials; mid-pex: mid-prevalence exact.

Table 4. *Salmonella* serovars obtained from abattoir and processing plant samples.

Line	Origin/source	Sampling locations*	Total No. of isolates	Serovars and number (n)
Abattoir line	Environment	Personnel's hand	5	*S.* Saintpaul (4), *S.* Kastrup (1)
		Aprons	5	*S.* Saintpaul (1), *S.* Larochelle (1), *S.* Muenchen (3)
		Knives	4	*S.* Saintpaul (1), *S.* Larochelle (1), *S.* Muenchen (2)
		Water	1	*S.* Saintpaul (1)
		Hooks	2	*S.* Larochelle (1), *S.* Muenchen (1)
		Floor	9	*S.* Saintpaul (4), *S.* Muenchen (2), *S.* Larochelle (2), *S. Dublin* (1)
		Refrigerator	6	*S.* Saintpaul (1), *S.* Larochelle (1), *S.* Muenchen (4)
		Trucks	5	*S.* Saintpaul (4), *S.* Muenchen (1)
		Total	37	
	ARM	Feces	8	*S.* Saintpaul (2), *S.* Larochelle (2), *S.* Dublin (1), *S.* Kastrup (1), unidentified (2)
		MLN*	3	*S.* Saintpaul (1), *S.* Muenchen (1), *S.* Kastrup (1)
		Raw meat	4	*S.* Saintpaul (2), *S.* Larochelle (1), *S.* Dublin (1),
	Sub total		15	
	Butcheries	Beef at butchery	11	*S.* Saintpaul (6), *S.* Larochelle (2), *S.* London (1), *S.* Dublin (1), Unidentified (1)
		Total	63	
Processing plant line	Environment	Personnel hands	1	Unidentified (1)
		Cutting plates	1	*S.* Eastbourne (1)
		Working tables	3	*S.* London (1), *S.* Concord (2)
		Room	3	*S.* Typhimurium (1), *S.* Eastbourne (1), Unidentified (1)
		Cutter	1	Unidentified (1)
		Filler/stuffer	1	Unidentified (1)
		Total	10	
	ARM	Raw meat	12	*S.* Saintpaul (1), *S.* Anatum (2), *S.* London (5), *S.* Muenchen (2), *S.* Eastbourne (1), Unidentified (1)
	Supermarkets	Supermarket-B	1	*S.* Muenchen (1)
	Sub total		23	
Grand total				**86**

ARM: animal-related materials; MLN: mesenteric lymph node.

Table 5. *Salmonella* serovars by sampling location and occasion (abattoir line).

Origin/source	Sampling locations	Total No. of isolates	Sampling occasions				
			Occasion 1 Serotype (n)	Occasion 2 Serotype (n)	Occasion 3 Serotype (n)	Occasion 4 Serotype (n)	Occasion 5 Serotype (n)
Environment	Personnel hands	5	*S.* Saintpaul (1)	*S.* Saintpaul (1) *S.* Kastrup (1)	*S.* Saintpaul (2)		
	Aprons	5		*S.* Saintpaul (1) *S.* Larochelle (1) *S.* Muenchen (1)			*S.* Muenchen (2)
	Knives	4		*S.* Saintpaul (1) *S.* Muenchen (1)	*S.* Larochelle (1)	*S.* Muenchen (1)	
	Water	1				*S.* Saintpaul (1)	
	Hooks	2	*S.* Muenchen (1)			*S.* Larochelle (1)	
	Room	9	*S.* Saintpaul (2) *S.* Dublin (1)	*S.* Saintpaul (1)	*S.* Saintpaul (1)	*S.* Larochelle (1) *S.* Muenchen (1)	S. Larochelle (1) *S.* Muenchen (1)
	Refrigerator	6			*S.* Saintpaul (1)	S. Muenchen (2)	*S.* Larochelle (1) *S.* Muenchen (2)
	Trucks	5	*S.* Saintpaul (1)	*S.* Saintpaul (1)	*S.* Saintpaul (2)		*S.* Muenchen (1)
ARM	Feces	8	*S.* Dublin (1)	Unidentified (2)	S. Saintpaul (2) *S.* Kastrup (1)	*S.* Larochelle (1)	*S.* Larochelle (1)
	MLN*	3			*S.* Saintpaul (1) *S.* Muenchen (1)	*S.* Kastrup (1)	
	Raw meat	4	*S.* Dublin (1)		*S.* Saintpaul (2)	*S.* Larochelle (1)	
Butcheries	Beef at butcheries	11	*S.* Saintpaul (2) *S.* London (1) *S.* Dublin (1)	*S.* Saintpaul (1) Unidentified (1)	*S.* Saintpaul (3)		*S.* Larochelle (2)

ARM: animal-related materials; MLN: mesenteric lymph node.

Abattoir line

S. Saintpaul was the predominant serotype (11.4%; 95% CI: 7.8–15.9), being present in all sampling locations with the exception of hooks (Table 4). *S.* Saintpaul was followed by *S.* Muenchen (5.9%) and *S.* Larochelle (4.6%). *S.* Dublin was observed only in room samples, animal feces, and raw meat at the abattoir and in the butcheries.

At the fifth sampling occasion, only two serotypes (*S.* Muenchen and *S.* Larochelle) were observed (Table 5). *S.* Dublin and *S.* London were observed only during the first sampling occasion. At the fourth sampling, the frequency of *S.* Muenchen and *S.* Larochelle was higher in environmental samples than in animal-related material and samples from the butcheries (0 isolates; Table 5).

With respect to sampling location, hand of personnel, aprons, and knives were frequently positive with *S.* Saintpaul, *S.* Muenchen, and *S.* Larochelle.

Processing plant line

S. London was obtained 5 times at the second sampling occasion, *S.* Eastbourne was observed at the fifth, seventh, and eighth sampling. All others were obtained only infrequently (Table 6).

S. Eastbourne was observed in samples from the environment and from animal-related material, while *S.* Muenchen was detected in raw meat and in the end product (supermarket). *S.* London was observed mostly in raw meat.

Discussion

Prevalence

The overall prevalence of 12.9% in this study was lower than that reported by Molla *et al*. [10], with 23.6% from food animals in Ethiopia, and similar to a study reporting 7.1% positive samples out of 323 cattle in Debre Zeit [8].

Abattoir line

The abattoir line produced a 26.6% prevalence, which was higher than the 10.9% reported by Sibhat *et al*. [3] in Ethiopia and also higher than the 7.2% prevalence reported by Teklu and Negussie [6] in a sheep and goat abattoir line at Modjo, Ethiopia, which was erected more recently and which possesses a clear and transparent technical line.

The occurrence of *Salmonella* in all sampling locations and occasions along this line may be due to the continuous influx of animals that contaminate abattoir and the equipment (floors, personnel) during processing.

Animal-related samples

The 23.5% result from animal feces was similar to the 19% found in rumen contents reported by Sibhat *et al*. [3], and higher than 2.2% in cattle feces [1], 3.1% in pooled feces [8], and 15.1% in camel feces [9].

Positive results from the lymph nodes indicate the infection status of the animals. The 8.8% result in the present study was similar with 8% reports of Sibhat *et al*. [3], but higher than the 4.2% found in slaughter

Table 6. Distribution of *Salmonella* serovars in positive sampling locations and occasions at processing plants.

Origin/ source	Sampling locations*	Positive	Sampling occasions							
			Occasion 1 Serotype (n)	Occasion 2 Serotype (n)	Occasion 3 Serotype (n)	Occasion 4 Serotype (n)	Occasion 5 Serotype (n)	Occasion 6 Serotype (n)	Occasion 7 Serotype (n)	Occasion 8 Serotype (n)
Environment	Personnel's hands	1							Unidentified (1)	
	Cutting plates	1					*S.* Eastbourne (1)			
	Working tables	3		*S.* London (1)				*S.* Concord (2)		
	Rooms	3				*S.* Typhimurium (1)			*S. Estbourne* (1)	Unidentified (1)
	Cutters	1								Unidentified (1)
	Fillers/stuffers	1	Unidentified (1)							
ARM	Raw meat	12	*S.* Anatum (2) *S.* London (1)	*S.* London (4)	*S.* Saintpaul (1)			*S.* Muenchen (2)	Unidentified (1)	*S.* Eastbourne (1)

ARM: animal-related materials.

cattle [1], 4.5% in 65 pooled fecal and mesenteric lymph node (MLN) samples [8], 5.0% (goats) and 5.6% (sheep) reported by Teklu and Negussie [6] at Modjo. Molla *et al*. [9] recovered 15.9% positive samples from camels in Ethiopia.

The abattoir environment was more frequently positive (36.6%) than were animal-related samples (14.7%). Incoming strains may establish themselves as a permanent in-house flora under poor cleaning and disinfecting conditions [7].

Environmental samples

Positive environmental samples ranged between 30.7% in knives and 60% in refrigerators. All results indicate heavy cross-contamination, which is true for people as well as for the surfaces of tools and equipment.

Among water samples, 8.3% were positive, similar to the results of Teklu and Negussie [6] in water used at Modjo abattoir (7.1%). Samples taken from the trucks were more frequently positive (45.5%), with rates as high as those of butcheries.

Samples from beef and butcheries

The prevalence in beef at the abattoir level (11.8%) was similar with the 9.8% rate reported by Nyeleti *et al*. [1], higher than the 2.8% and 3.1% rates [8], 2% [3] from carcass swabs at a beef abattoir, and lower than 42.8% (n = 236) reported from Senegal [21]. It was similar to the rates of 11.9% and 9.8% found in the diaphragm and abdominal muscles, respectively [1].

The 32.4% positive results in raw beef at the butcheries were similar to findings at the abattoir, lower than the 87.4% rate reported by Stevens *et al*. [21] from retail beef in Senegal and the 60% rate found among samples from a South African slaughterhouse [22].

The number of positive samples at the butcheries and in animal-related material was high as well, indicating possible transfer from the abattoir into the butcheries and from there into the human habitat.

Processing plant line

Only a few environmental locations were positive along the processing plant line. Of these, the 5.2% prevalence observed from personal hand swabs at the processing plant was similar to the 7% rate reported by Sibhat *et al.* [3] and the 10.6% reported by Teklu and Negussie [6] from hand samples. The 17.7% prevalence obtained from working tables was lower than the 96.4% at permanent markets and 70% at districts sales places on wood and cardboard [21]. Cutting plates, floors, as well as cutters and stuffers were positive as well.

Meat and mortadella

Starting with a 10.5% *Salmonella* prevalence in the processing plant, in 119 mortadella samples, only 1 sample was positive.

In comparison, higher positive numbers were obtained from raw products, *e.g.*, 7.9% in minced beef [1], 14.4% in minced beef, 14.1% in mutton, and 16.4% in pork from a supermarket in Addis Ababa [2]. Our data indicate the different kind of commodities exposed to *Salmonella* contamination risk. The application of heat treatment destroys *Salmonella* and lowers the risk of product contamination.

Ejeta *et al*. [2] investigated samples from supermarkets; *S.* Anatum (in 13% and 8.3% of minced beef and mutton, samples, respectively), *S.* Saintpaul (in 4.3% of minced beef samples), and *S.* Dublin (in 4.3% of minced beef samples) were found.

Serotypes

S. Saintpaul, *S.* Muenchen, and *S.* Larochelle were the main serotypes observed in most of the sampling locations in the abattoir line, which have been obtained also in other studies from Ethiopia [2,3,9,13,14]. In contrast, Stevens *et al*. [21] isolated mainly *S*. Bredeney (71), *S.* Corvallis (12), *S*. Kentucky (10), *S.* Muenster (21), and *S.* Waycross (18) from Senegal, which may reflect differences in the geographic distribution of *Salmonella*.

The 1.2% *S*. Typhimurium proportion was lower than the 20% reported by Alemayehu *et al.* [8]. Investigations in children from Addis Ababa and Jimma [13] yielded *S.* Typhimurium in 0.8% and 0.3% of cases, respectively, with an overall prevalence of 0.7% in hospitals.

The presence of *S*. Dublin was slightly higher than the 2.4% reported by Ejeta *et al*. [2] but lower than the 48% reported by Alemayehu *et al*. [8].

Investigations in an abattoir in Ethiopia yielded *S.* Dublin (cattle, personnel, minced beef), with 54% positive samples [1].

The 2.3% proportion of S. Anatum found in this study is similar to the 2.6% reported by Molla *et al.* [9] from camels, but lower than the 9.1% reported by Ejeta *et al*. [2]. *S.* Anatum was the most reported serotype (62.1%) in the study of Sibhat *et al*. [3]. This was also the case in a study from an abattoir in Algiers, Algeria [23], where *S.* Anatum was the predominant serotype among *Salmonella* isolates.

S. Saintpaul was the predominant serotype isolated in this investigation. The present 32.5% *S.* Saintpaul percentage was similar with the 38.8% reported by

Molla *et al*. [9] in camels, but lower than the 2.3% reported by Ejeta *et al*. [2]. Comparing both abattoir and processing line, the prevalence of *S.* Saintpaul was higher in the abattoir line than at the processing plant line (0.25%; 95% CI: 0.01–1.13) ($p < 0.05$).

The 19.8% proportion of *S.* Muenchen was higher than the 8.6% reported by Molla *et al*. [9] from camels and higher than the 0.7% from pigs reported by Aragaw *et al*. [14] in Ethiopia.

The prevalence of *S.* Concord was low (0.3%). Beyene *et al*. [13] reported an overall 4.2% prevalence with 5.2% at Addis Ababa and 2.3% at Jimma Hospitals as a major pathogen in children with diarrhea in Ethiopia.

The present 0.5% positive sample for *S.* Eastbourne was lower than the 15/278 in caecal contents, 21/278 in MLN, and 3/277 in carcass swabs reported by Aragaw *et al*. [14] from pigs at abattoir in Ethiopia.

Sibhat *et al*. [3] obtained *S.* Eastbourne from cattle hides, MLN, and from a carcass surface.

Conclusions

Salmonella has been reported from foods and the food production environment, with outbreaks occurring in the human population worldwide.

The structured survey presented in this study was aimed at *Salmonella* serotypes' detection in two beef production lines (a beef abattoir line and a processing line) in Addis Ababa, Ethiopia. The study results indicated the presence of this agent in animal-related materials, in the abattoir line environment, and in a heat-treated beef product (mortadella). The application of heat treatment to the screened products, which is able to destroy *Salmonella* during the steam cooking operation, lowers the risk of contamination.

Finally, isolation of *S.* Kastrup and *S.* London for the first time in Ethiopia also suggests the possible presence of diversified *Salmonella* serotypes. Hence, national based *Salmonella* surveys in food and food production and processing lines are recommended.

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