Article— Artikel

Retrospective study on the incidence of *Salmonella* isolations in animals in South Africa, 1996 to 2006

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ABSTRACT

A retrospective study that involves the analysis of laboratory diagnostic data collected during the period 1996–2006 was conducted. A total of 3417 *Salmonella* isolations involving 183 different serotypes was recorded from 1999–2006, inclusive, at the Onderstepoort Veterinary Institute, Agricultural Research Council, South Africa. The most common serotypes were *Salmonella enterica* subspecies *enterica* serovar Typhimurium (917 incidents), *Salmonella enterica* subspecies *enterica* serovar Dublin (248 incidents), *Salmonella enterica* subspecies *enterica* serovar Enteritidis (232 incidents), *Salmonella enterica* subspecies *enterica* serovar Muenchen (164 incidents), *Salmonella enterica* subspecies *enterica* serovar Heidelberg (118 incidents) and *Salmonella enterica* subspecies *enterica* serovar Chester (113 incidents). The number of recorded *Salmonella* isolations over the period 1996 to 2006 varies considerably from year to year. The peak of 693 isolations was recorded in 1997, and the lowest, 108 incidents, in 2001. Of the total incidents recorded during the period of survey, 2410 (70.5 %) occurred in poultry and other birds, 641 (18.75 %) occurred in cattle, 255 (7.46) in pigs and 111 (3.24 %) in sheep. Despite the large number of serotypes isolated (183), 52 % of incidents were due to only 6 serotypes in decreasing order of prevalence: S. Typhimurium, S. Dublin, S. Enteritidis, S. Muenchen, S. Heidelberg and S. Chester. Serovar Typhimurium was the most common serotype and was detected in all animal species sampled, with, 65 % (598) of the incidents occurring in poultry and 20 % (187) occurring in cattle. Of the total of 248 incidents of S. Dublin serotype, 95.6 % (237) of incidents occurred in cattle and of the 232 isolates of S. Enteritidis, 223 (96%) originated from poultry. Serovar Choleraesuis was identified in 16 isolates from pigs. The following 4 serotypes were each recorded in more than 50 incidents: S. Hadar (102), S. Schwarzengrund (99), S. Mbandaka (94) and S. Sandiego (73). The trends of annual incidence of *Salmonella* infection in cattle, sheep, pigs, poultry and other birds during the 11-year period and the distribution of the main serotypes in individual species of animals from 1996–2006 are discussed.

Keywords: incidence, livestock, *Salmonella enterica*, South Africa.

Kidanemariam A, Engelbrecht M, Picard J **Retrospective study on the incidence of *Salmonella* isolations in animals in South Africa, 1996 to 2006.** *Journal of the South African Veterinary Association* (2010) 81(1): 37–44 (En.). Onderstepoort Veterinary Institute, Agricultural Research Council, Private Bag X05, Onderstepoort, 0110 South Africa.

INTRODUCTION

Salmonellosis in farm animals and its association with human infection has attracted increasing attention in many countries[4,,24,28,33]. It is well recognised that the incidence of *Salmonella* infection in various species of farm animals is closely linked with husbandry methods and that intensive farming methods are conducive to the spread of infection and a resulting rise in clinical disease. In fact, in many countries such as Sweden, salmonellosis is a controlled disease where especially poultry farms are routinely monitored for the presence of *Salmonella* species and if present, measures are taken to eradicate the agent[3]. Using these programmes, the incidence of salmonellosis in a given species of animal can be reduced to a level at which it is no longer of economic or clinical importance, provided that satisfactory diagnostic methods are available and appropriate control measures are instituted based on the diagnostic test results. This is well illustrated by the reduction in the incidence of S. Pullorum and S. Gallinarum infection in the European Union, resulting from the compulsory blood testing programme in poultry establishments[3].

In South Africa, S. Enteritidis, and since 2008 S. Gallinarum are notifiable diseases. In spite of this, many farms, especially poultry farms, are monitoring for salmonellae and taking measures to eradicate the agents. Salmonellosis in cattle in South Africa is frequently diagnosed in calves, but it is only rarely encountered as a clinical problem in adult cattle[28]. Although an accurate estimate of the occurrence of salmonellosis in cattle in southern Africa is not available, its importance is likely to be similar to that in many other parts of the world[17]. Although present in pigs, salmonellosis is generally considered by this industry to be of lesser importance compared with the other diseases. Clinical salmonellosis in pigs may, however, become economically important in South Africa as the prevalence of porcine circovirus-2 increases[1]. Furthermore, multiresistant S. Typhimurium strains that are potentially of public health significance have been identified from pigs [26].

Non-typhoid salmonellosis is by far the most frequently reported food-borne zoonotic disease across the globe. Epidemiological investigations have shown that poultry, poultry products, pork and raw milk are the most common sources of sporadic outbreaks of human salmonellosis[19,20,32].

The Bacteriology Laboratory at the Onderstepoort Veterinary Institute (ARC-OVI) is regarded as the referral laboratory for the serotyping of salmonellas of animal origin in South Africa. It therefore receives the vast majority of salmonellae of animal origin for serotyping from provincial and private veterinary laboratories. Some salmonellae are, however, cultured and typed at other laboratories and are not included in this survey.

The purpose of this review is therefore to present retrospective laboratory serotyping data from the ARC-OVI between 1996 and 2006 in livestock in South Africa.

MATERIALS AND METHODS

Samples and laboratory serotyping

The Bacteriology Laboratory of ARC-OVI receives *Salmonella* strains for serotyping from all provinces in the country. The laboratory also performs the isolation and identification of *Salmonella* species. The bacterial strains were isolated from animal and non-animal sources. Only those Gram-negative strains that were indole-

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Received: August 2009. Accepted: February 2010.

negative, motile, Simmond's citrate-positive, urease negative, produced hydrogen-sulphide in a triple sugar iron (TSI) slant, lysine decarboxylase positive, fermented dulcitol but did not ferment lactose and were malonate negative were considered to be *Salmonella enterica*[9] and were serotyped. Exceptions were S. Pullorum and S. Gallinarum which are non-motile.

Serotyping of the *Salmonella* species was done by the slide agglutination test using polyvalent and monovalent antisera raised against the somatic (O) antigen and flagellar (H) antigen (BioRad PLC, Davies, PLC). Serovar identification was done by comparing the antigenic formula of strains with those described in the Kauffmann-White Scheme[22].

Data management

All relevant diagnostic data generated by the laboratory were recorded in a data-capturing format and entered into a Microsoft 2003 Excel™ spreadsheet for subsequent analysis. Descriptive statistics were employed to analyse the proportions of each serovar related to every animal species.

RESULTS

Total incidence of salmonella infection in different species of animals during the 11-year period 1999–2006 inclusive

The total number of incidents and distribution of various *Salmonella* serotypes in cattle, pigs, sheep, poultry and other birds, in South Africa are shown in Table 1. The 9 most common serotypes are listed in order of frequency, followed by the remainder in alphabetical order.

Of a total of 3417 incidents reported during this period and associated with 183 different serotypes, 2410 occurred in poultry and other birds (155 serotypes), 641 in cattle (66 serotypes), 255 in pigs (32 serotypes) and 111 in sheep (22 serotypes).

Despite the large number of serotypes isolated, the majority of incidents were due to relatively few serotypes. Moreover, with the exception of S. Typhimurium, which accounted for 917 incidents in all species of animals, the other commonly occurring serotypes had a relatively high degree of host specificity. Thus S. Dublin, the cattle-adapted serotype, was by far the most common serotype encountered in cattle (237 incidents), but was also rarely isolated in sheep (8 incidents). Serovar Enteritidis and S. Gallinarum were, with a few exceptions, confined to birds. All the serovar *Choleraesuis* strains originated from pigs.

Table 1: **Number and serotypes of *Salmonella* isolations in animals in South Africa during the period 1999–2006.**

Serovar	Cattle	Poultry	Sheep/goat	Pig	Total
S. Typhimurium	187	598	42	90	917
S. Dublin	237	3	8		248
S. Enteritidis	6	223	2	1	232
S. Muenchen	16	109	9	31	165
S. Chester		113	1		114
S. Heidelberg	1	117			118
S. Hadar	1	100		1	102
S. Schwarzengrund	2	93		4	99
S. Mbandaka	4	90			94
S. Aarhus	2	14		1	17
S. Aba		17		1	18
S. Aberdeen	1	23	1		25
S. Ablogame				2	2
S. Alachua	1				1
S. Agona		23		11	34
S. Agoueve		2			2
S. Alamo		5			5
S. Amager	2	3			5
S. Amsterdam		1			1
S. Anatum	8	33	1	2	44
S. Baiboukoum	1				1
S. Bertha	1				1
S. Bispebjerg		6		1	7
S. Blockley	5	35		1	41
S. Bovismorbificans	11	1		1	13
S. Bradford		15	2	2	19
S. Braenderup	1	7			8
S. Brancaster	2	6	1		9
S. Brandenburg		3			3
S. Bredeney		2			2
S. Bonn		35			35
S. Bristol		1			1
S. Carno	3	1			4
S Cerro		3			3
S. Charlottenburg		1			1
S. Choleraesuis				16	16
S. Chicago		5			5
S. Chile	9				9
S. Chincol	1				1
S. Chingola		1			1
S. Cleveland		1			1
S. Coeln	1				1
S. Colorado	1	2			3
S. Concord	1	2			3
S. Cubana		1			1
S. Dakar				2	2
S. Derby	1	6		22	29
S. Dessau		1			1
S. Doncaster	2				2
S. Donna		1			1
S. Drogana		2			2
S. Duesseldorf			2		2
S. Duisburg	2	12			14
S. Durban	1	7			8
S. Edinburg	6	7			13
S. Elomrane	2	1			3
S. Escanaba			1		1
S. Fallowfield		1			1
S. Essen		1			1
S. Farmsen		1			1
S. Gallinarum	1	21			22
S. Gaminara			3		3
S. Gatineau		1			1
S. Georgia		6			6
S. Glostrup		6			6
S. Godesburg		1			1

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Table 1 (*continued*)

Serovar	Cattle	Poultry	Sheep/goat	Pig	Total
S. Goettingen		1			1
S. Gombe		1			1
S. Garmpian		3			3
S. Hayindogo		1			1
S. Havana		1			1
S. Herston	2	6			8
S. Hidalgo	1				1
S. Hindmarsh	2	2			4
S. Hvittingfoss		3			3
S. Indiana		2			2
S. Infantis	13	41	7	3	64
S. Irumu		18			18
S. Isangi		15			15
S. Java		1			1
S. Jerusalem	11	1			12
S. Joal		1		1	2
S. Johannesburg		1			1
S. Jukestown		1			1
S. Kande		2			2
S. Kalumburu			5		5
S Kapemba	2				2
S. Kentucky	1	8	1		10
S. Kiambu		8			8
S Kibi		2			2
S. Kibusi		2			2
S. Kingston		2			2
S. Kisii		2			2
S. Kotu	2				2
S. Kottbus		2			2
S. Kouka		5			5
S. Lamberhurst		2			2
S. Lexington		1			1
S. Lille		1			1
S. Lindenburg		1	1		2
S. Liverpool		1			1
S. Livingstone		4			4
S. Lode		1			1
S. London		1			1
S. Lovelace		2			2
S. Maiduguri		3			3
S. Malakal			1		1
S. Manhattan	2	14			16
S. Madjorio		1			1
S. Marshall		1			1
S. Massenya		1			1
S. Menston	1				1
S. Minnesota		2			2
S. Mkamba		1			1
S. Montevideo	1	3			4
S. Moscow		1			1
S. Naestved		1			1
S. Neudorf		2			2
S. Neukoelln	1	5			6
S. Neuloelln		1			1
S. Nessziona		1		1	2
S. Newlands		1			1
S. Newport	1	15		2	18
S. Newyork		1			1
S. Nyanza		1			1
S. Ohio		2			2
S. Onderstepoort	2	1			3
S. Orion	1	10	1		12
S. Oritamerin		3			3
S. Othmarschen	1	9			10
S. Panama		2		10	12
S. Papuana		6			6
S. Poitiers		1			1

Continued on p. 40

Other serotypes frequently reported, namely S. Muenchen (165 incidents), S. Heidelberg (118 incidents), S. Chester (114 incidents), S. Hadar (102 incidents), S. Mbandaka (94 incidents) and S. Schwarzengrund (93 incidents) were found mainly in poultry and other birds.

Of the total number of incidents reported in all species of animals, 26.8 % were due to S. Typhimurium infection (917 incidents), 7.3 % to S. Dublin (248 incidents), 6.8 % to S. Enteritidis (232 incidents), 4.8 % to S. Muenchen (165 incidents), 3.3 % to S. Chester (114 incidents), 3.4 % to S. Heidelberg (118 incidents), 2.9 % to S. Hadar (102 incidents), 2.7 % to S. Mbandaka (94 incidents), 2.9 % to S. Schwarzengrund (99 incidents), 2.1 % to S. Sandiego (73 incidents), 1.8 % to S. Infantis (64 incidents), 1.3 % to S. Anatum (44 incidents) and 1.2 % to S. Blockley (41 incidents).

The remaining 170 serotypes (1106 incidents) collectively accounted for 32.3 % of the total incidents.

The annual incidence of *Salmonella* strains in cattle, sheep, pigs and poultry is shown in Table 2, which indicates a slight increase in the incidence of infection in cattle and similarly slight decrease in the incidence in poultry. There was a slight increase in the number of incidents in sheep from year to year.

The data in Table 2 show that the total number of *Salmonella* incidents reported in 1997 increased by 206 % compared with 1996 and increased by 170 % compared with 2005. However, this was not consistent throughout the survey period. The proportion of *Salmonella* incidents in 2001 was low and accounted for only 3 % of the total reported incidents. Over the 11-year survey period, *Salmonella* incidents reported were significantly higher in avian species than the other species. The incidents in avian species accounted for 70.5 % of the total incidents reported during the same period.

Salmonella infection in cattle

The main features of the annual incidence of *Salmonella* infection in cattle are presented in Table 4.

Of a total of 641 incidents of *Salmonella* infection, 36.9 % were due to S. Dublin (237 incidents) and 29 % to S. Typhimurium (187 incidents). Thus 66 % of all incidents were due to these 2 serotypes. Sixty-four other serotypes accounted for the remaining 34 % of incidents (Table 4).

The highest number of incidents in cattle occurred in 2006 (Table 1). This was due to a dramatic rise in S. Typhimurium incidents (Table 4) to 51 (65 %), the highest number ever recorded since 1996. Since 1996 the annual incidence has declined to 30 (4.7 %) in 2001. This is partly

Table 1 (*continued*)

Serovar	Cattle	Poultry	Sheep/goat	Pig	Total
S. Potsdam	1	1			2
S. Pretoria	1				1
S. Putten		1			1
S. Raus		3			3
S. Reading	4	6			10
S. Regent		3			3
S. Rideau	1	1		2	4
S. Riggil		3			3
S. Rostock		1			1
S. Rubislaw		3			3
S. Ruiru	1	12			13
S. Saintpaul		8			8
S. Salford	1			1	2
S. Sandiego	5	68			68
S. Sandow		4			4
S. Sao		3			3
S. Senftenburg	1	39		1	41
S. Senegal		1			1
S. Somone		1			1
S. Skansen		1			1
S. Southampton		1			1
S. Stanley	1	1			2
S. Stratford				1	1
S. Stoneferry		3			3
S. Svedvi	1				1
S. Sundsvall		1			1
S. Tambacounda	1	3			4
S. Tanzania		3			3
S. Tees		2			2
S. Tennessee		16			16
S. Tennyson				1	1
S. Thies			1		1
S. Thompson		12			12
S. Tokoin		2			2
S. Tsevie		4			4
S. Tshiongwe	1	3			4
S. Uganda				1	1
S. Umbilo	1				1
S. Vejle		2			2
S. Virchow		27		1	28
S. Wagenia		1			1
S. Warnemuende	3				3
S. Westhampton		5			5
S. Wil		2			2
S. Wippra		3			3
S. Worthington	1	1			2
S. Yardley		1			1
S. Zanzibar		1			1

due to the lower incident rate of S. Typhimurium recorded (2.2 %). However, in 2006 S. Typhimurium incidents reached a level of 51 (27.3%), the highest recorded for the period investigated.

Salmonella infection in poultry

The term 'poultry' includes domestic fowl, turkeys and ostriches. In all, 2410 incidents of *Salmonella* infection in poultry were diagnosed during 1996–2006 at the OVI (Table 5). Five hundred and ninety-eight incidents (24.8 %) were due to S. Typhimurium. Next in order of frequency was S. Enteritidis, with 223 incidents (9.3 %), followed by S. Heidelberg with 117 incidents (4.8 %), S. Chester with 113 (4.7%),) S. Muenchen with 109 (4.5 %), and S. Hadar with 100 (4.2 %). One hundred and forty-eight other serotypes accounted for the remaining 1150 cases (47.7 %).

Serovar Typhimurium was listed as the most common serotype (24.8 % of the total incidents) in this survey. The percentage of incidents due to this serotype varied from 43.5% in 1999 to 38.5 % in 2002; during 2006, 7.4 % incidents were recorded.

Serovar Enteritidis was second in frequency of isolation during the present survey (223 incidents) and the proportion of incidents due to this serotype varied from 11 % in 1996 to 23.7 % in 1998; during 2006, 5.9 % incidents were recorded.

The annual incidence of *Salmonella* infection rose significantly from 263 in 1996 to 625 in 1997 (see Table 5), but thereafter there was no regular trend in the annual incidence, largely due to irregular patterns in the isolation of the most common *Salmonella* serovars.

Salmonella infection in pigs

The incidence of *Salmonella* infection in pigs during the 11-year period is presented in Table 6. Although salmonellosis, especially S. Choleraesuis infection, can be a serious problem in pigs, its incidence was relatively low. Of the 255 incidents diagnosed during this period 90 (35.3 %) were due to S. Typhimurium, 31(12.2%) to S. Muenchen, 22 (8.6%) to S. Derby and 16 (6.3 %) to S. Choleraesuis. The remaining 96 incidents (37.6 %) were distributed between 28 other serotypes. Annual variations in incidents were mainly due to changes in the incidence of S. Typhimurium as this was by far the most common serotype involved. Although S. Muenchen was the second in frequency of isolation (22 incidents), it was reported on only 2 occasions during the survey period.

Salmonella infection in sheep

A total of 111 incidents of *Salmonella* infection in sheep, involving 21 serotypes, were reported during the 11-year period of the present survey. The main features are shown in Table 7. Of the 111 incidents diagnosed during this period 42 (37.8 %) were due to S. Typhimurium, 9(8.1%) to S. Muenchen, 8(7.2%) to S. Dublin and 7(6.3 %) to S. Infantis. The remaining 45 incidents (40.5 %) were distributed between 17 other serotypes. The percentage of infections in sheep due to serotypes other than the above has increased markedly from less than 25 % in 2003 to nearly 62 % in 2005. During 2006, these serotypes accounted for 47.6 % of the total incidents.

DISCUSSION

Since there is no coordinated effort to survey animals in South Africa for the presence of *Salmonella,* laboratory reports based on samples from diseased animals, abattoir and animal feed surveillance will continue to provide important information on the presence of *Salmonella* in livestock in this country. As this laboratory serves as a referral centre to all the State-run veterinary laboratories and is also used by many private laboratories for the serotyping of salmonellae, it gives a good indication of the prevalence of *Salmonella* infections in livestock in South Africa.

Over 2500 *Salmonella* serotypes are now internationally recognised[8,21] and the

Table 2: **Number of *Salmonella* isolations per species per year.**

Species	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
Avian	263	625	118	177	258	70	65	124	276	299	135	2410
Bovine	63	57	75	72	46	30	55	57	51	57	78	641
Ovine	7	3	5	21	6	4	11	9	0	24	21	111
Porcine	3	8	75	44	11	7	12	24	21	26	24	255
Total	336	693	273	314	321	111	143	214	348	406	258	3417

Table 3: **Number of incidents of *Salmonella* serotypes affecting only 1 animal species diagnosed by OVI, 1996–2006.**

Animal species	*Salmonella* serotype	Frequency of incidents	% Frequency
Cattle	S. Dublin	237	95.6
Poultry	S. Enteritidis	223	96
Pig	S. Choleraesuis	16	100

Table 4: **Common *Salmonella* isolates in cattle in South Africa.**

Serotype		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
S. Dublin	Count	16	21	23	31	25	18	21	24	25	18	15	237
	%	25.4	36.8	30.6	40	54.3	60	38.2	42.1	49	31.6	19.2	36.9
S. Typhimurium	Count	19	13	25	19	11	4	10	16	7	12	51	187
	%	30.2	22.8	33.3	26.4	23.9	13.3	18.2	28.1	13.7	20.1	65.4	29.2
Other serotypes	Count	28	23	27	22	10	8	24	17	19	27	12	217
	%	44.4	40.4	36	30.6	21.7	26.7	43.6	29.8	37.2	47.3	15.4	33.8
Total incidents		63	57	75	72	46	30	55	57	51	57	78	641
Number of identified serotypes		14	11	14	15	10	5	10	8	10	9	6	66

number continues to increase every year. However, despite the existence of such a formidable number of different serotypes, only a few of these are frequently associated with clinical diseases in animals and humans[31]. Those salmonellae that are considered to be highly host-adapted, *i.e.* S. Dublin in cattle, and S. Gallinarum and S. Pullorum in chickens tend to cause clinical disease in their host-species, but only rarely in other species. However, other serovars such as S. Enteritidis in poultry and S. Choleraesuis in pigs tend to easily infect other species and are occasionally responsible for infections in humans and other animals[2]. The ubiquitous species, S. Typhimurium, infects a wide host range and is the most common serovar isolated in human non-typhoidal infections, especially humans infected with human immunodeficiency virus (HIV)[15].

Despite the fact that more than 180 serotypes were characterised in this laboratory, the majority of incidents were due

Table 5: **Common *Salmonella* isolates in poultry in South Africa.**

Serotype		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
S. Typhimurium	Count	77	168	32	77	71	0	25	23	71	44	10	598
	%	29.3	26.9	27	43.5	27.5	0	38.5	18.5	25.7	14.7	7.4	24.8
S. Enteritidis	Count	29	94	28	9	3	3	10	13	0	26	8	223
	%	11	15	23.7	5	1.2	4.3	15.4	10.5	0	8.7	5.9	9.3
S. Heidelberg	Count	3	4	0	0	16	4	2	14	3	16	55	117
	%	1.1	0.64	0	0	6.2	5.7	3.1	11.3	1.1	5.3	40.7	4.8
S. Chester	Count	1	37	1	10	9	1	0	20	13	20	1	113
	%	0.4	5.9	0.85	5.6	3.5	1.4	0	16.1	4.7	6.7	0.7	4.7
S. Muenchen	Count	11	4	6	7	28	7	4	15	8	17	2	109
	%	4.2	0.64	5.1	5.9	10.8	10	6.1	12.1	2.9	5.7	1.5	4.5
S. Hadar	Count	39	8	1	1	22	2	4	0	18	4	1	100
	%	14.8	1.3	0.85	0.56	8.5	2.8	6.2	0	6.5	1.3	0.74	4.15
Other serotypes	Count	103	310	50	73	109	53	20	39	163	172	58	1150
	%	39.2	49.6	42.4	41.2	42.2	75.7	30.7	31.4	59	57.5	42.9	47.7
Total incidents		263	625	118	177	258	70	65	124	276	299	135	2410
Number of identified serotypes		46	66	30	42	48	31	16	22	29	33	31	155

Table 6: **Common *Salmonella* isolates in pigs in South Africa.**

Serotype		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
S. Typhimurium	Count	2	2	41	7	3	4	2	1	9	15	4	90
	%	66.7	25	54.7	15.9	22.3	57.1	16.7	4.2	42.8	57.7	16.7	35.3
S. Muenchen	Count	0	0	27	0	0	0	0	4	0	0	0	31
	%	0	0	36	0	0	0	0	16.7	0	0	0	12.1
S. Derby	Count	0	0	0	17	1	0	0	0	1	2	1	22
	%	0	0	0	38.6	9.1	0	0	0	4.7	7.7	4.2	8.6
S. Choleraesuis	Count	0	0	0	0	4	1	0	3	4	1	3	16
	%	0	0	0	0	36.4	14.3	0	12.5	19	3.8	12.5	6.3
Other serotypes	Count	1	6	7	20	3	2	10	16	7	8	16	96
	%	33.3	75	9.3	45.5	27.3	28.6	83.3	66.7	33.3	30.7	66.7	37.6
Total incidents	Count	3	8	75	44	11	7	12	24	21	26	24	255
Number of identified serotypes	Count	2	6	7	6	6	4	6	7	9	7	8	32

Table 7: **Common *Salmonella* isolates in sheep in South Africa.**

Serotype		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
S. Typhimurium	Count	2	0	2	8	3	2	5	1	0	13	6	42
	%	28.6	0	40	38.1	50	50	45.4	11.1	0	30.9	28.6	37.8
S. Muenchen	Count	0	1	0	3	0	0	0	5	0	0	0	9
	%	0	33.3	0	14.3	0	0	0	55.6	0	0	0	8.1
S. Dublin	Count	0	0	1	0	1	0	0	1	0	0	5	8
	%	0	0	20	0	16.7	0	0	11.1	0	0	23.8	7.2
S. Infantis	Count	0	0	0	2	0	0	2	0	0	3	0	7
	%	0	0	0	9.5	0	0	18.2	0	0	7.1	0	6.3
Other serotypes	Count	5	2	2	8	2	2	4	2	0	26	10	45
	%	71.4	66.7	40	38.1	33.3	50	36.4	22.2	0	61.9	47.6	40.5
Total incidents	Count	7	3	5	21	6	4	11	9	0	42	21	111
Number of identified serotypes	Count	3	3	4	6	4	3	5	4	0	5	6	22

to only a few serotypes: 13 serotypes were responsible for 67.7 % of the total incidents (Table 1). Serovar Typhimurium was by far the most common, being recorded in 917 incidents (representing 26.8 % of the total), the majority of which occurred in poultry (598 incidents) in which it accounted for 65 % of the incidents. It was also the most common serotype reported in cattle (187 incidents), pigs (90 incidents) and sheep (42 incidents). As expected, the host-adapted serotypes such as S. Dublin, S. Choleraesuis and S. Enteritidis were almost exclusively isolated from cattle, pigs and poultry respectively. The low numbers of S. Gallinarum isolated from chickens was unusual but not unexpected. Biotyping methods identified these bacteria as S. Gallinarum and not S. Pullorum. Serovar Gallinarum is a common cause of septicaemia in layers and is frequently isolated by laboratories specialising in poultry diagnostics (J Picard, pers. obs., 2007), and is usually identified based on biochemical tests. At this stage it should also be noted that some laboratories have a limited capacity to serotype their own *Salmonella* strains and therefore many will identify common serotypes, but will not identify the unusual ones. The true country prevalence figures for S. Typhimurium, S. Dublin, S. Choleraesuis and S. Enteritidis may even be higher than presented here.

The present survey, covering 11 years from 1996 to 2006, shows more or less similar proportions of salmonella isolations in animals in South Africa (see Table 2). A notable exception is the proportion of *Salmonella* isolation in 1997 which reached the highest peak of 693, which is a 2fold increase from 1996 during which only 336 incidents were recorded. This increase in the total incidence was chiefly due to a rise in the number of incidents in poultry due to S. Typhimurium (168 incidents), S. Enteritidis (94 incidents) and S. Mbandaka (76 incidents) which altogether accounted for 338 reported incidents. One of the contributing factors to an increased incidence in the isolation of *Salmonella* serovars in poultry in the year 1997 may be linked to a policy shift in the country that stimulated the import of huge quantities of poultry products from abroad, and as the result there was a parallel increase in laboratory testing to ensure the safety and quality of the imported products (M Engelbrecht, pers. obs., 2008). There was also a slight peak in the isolation of salmonellae in poultry in 2005 and this could be attributed to the massive outbreak of velogenic Newcastle disease in poultry in South Africa as the result of which there may have been more chickens presented for necropsy and culture (J Picard, pers. obs., 2005). Often, when there are high mortalities in any species, the incentive to look for possible causal sources other than the main cause would also increase. It is also noted that there was a slight decrease in the number of *Salmonella* isolations in 2000 and 2001. This may be associated with a laboratory crisis rather than a genuine decrease in prevalence. However, care must also be taken when comparing data from one year with another as an increase or decrease in the number of isolations does not necessarily indicate a similar change in prevalence. This is because the total number of cases examined and their distributions are not known.

Serovar Dublin and S. Typhimurium are the 2 predominant serotypes detected in cattle, accounting for 66 % of the total recorded incidents. It has been shown elsewhere that S. Dublin is the most frequently isolated *Salmonella* serotype in clinical cases in cattle [34]. A similar study has also shown that S. Typhimurium is the 2nd most important serotype, after S. Dublin, involved in clinical outbreaks of salmonellosis in dairy herds in the Netherlands[36].

The relative incidence of S. Dublin in cattle had been consistently higher than the incidence of S. Typhimurim until 2006, when the proportion of S. Typhimurium incidents to those due to S. Dublin changed to a ratio of about 3:1. Earlier work indicated that the incidence of one serotype compared to another may differ from time to time for various reasons[27]. It is considered that these differences could be due to greater use of the live S. Dublin vaccine and managerial policies resulting in the removal of suspect S. Dublin carriers. Furthermore, an increase in animals that received rations of stored feed or greater rodent populations may have contributed to the increase in S. Typhimurium strains being cultured[6].

It should be noted that the epidemiology of S. Typhimurium and S. Dublin varies considerably. Cattle infected with S. Dublin invariably continue to excrete large numbers of organisms in their faeces for many years and often for life[14,25]. Removal of cattle chronically infected with this serotype is therefore a logical control measure following implementation of appropriate control strategies to limit environmental, water, and feed related pathogen spread[28]. The period of excretion of S. Typhimurium is usually limited to a few weeks or months after clinical recovery[11]. It is known that S. Typhimurium strains from cattle tend to persist in the environment for long periods. In Great Britain, phage typing was able to show that certain phage types of S. Typhimurium found in cattle can persist for years and then are later replaced by another phage type[23].

Serovar Enteritidis was mainly isolated from poultry with the overall incidence rate of 9.3 % (223 incidents). This serotype is among the most common pathogens of chickens that could also adversely affect human health following exposure to infected or contaminated chicken products[18,30]. Furthermore it can also cause serious disease in other livestock species such as cattle and sheep.

Serovar Choleraesuis was reported in 16 incidents (6.3%), but it was confined to pigs in which it was the 4th commonest serotype. This porcine serotype tends to cause septicaemic disease in humans in Asia where there are high pig densities[5].

Although the epidemiology of salmonellosis caused by different *Salmonella* serotypes can be vastly different, relatively more research has been done on risk factors for *Salmonella* species as a group than for the specific *Salmonella* serovars[10,34]. The presence of a wide range of *Salmonella* serotypes in animal foodstuffs and fertilisers has attracted much interest in recent years. Poultry manure and litter which are commonly used as feed supplements because of their high nitrogen content are one source of *Salmonella* infection in animals[31]. A laboratory result (OVI, unpubl. data 2007) showed that feed samples submitted for the detection of *Salmonella* species proved to contain *Salmonella* serotypes and it is possible that contaminated foodstuffs may be a source of infection to animals in South Africa.

Faecal waste represents the largest reservoir of *Salmonella* on animal farms. A number of studies have examined the survival of this bacterium in animal waste maintained under anaerobic and aerobic conditions[12]. During an outbreak and even on farms with endemic *Salmonella* infections, the prevalence of faecal shedding of this bacterium may approach 90 %[16]. This would explicitly indicate another possible source of *Salmonella* infection in livestock in South Africa, where dung and livestock enclosure wastes could be used as manure fertilisers.

The public health significance of these bacteria should never be underestimated. Previous studies conducted in Gauteng province in 2004 in chicken carcasses entering the human food chain showed the presence of *Salmonella* species[35]. Studies from other countries have also shown that outbreaks and individual cases of salmonellosis in humans are most frequently associated with food products of animal origin and include eggs, meat, and milk byproducts[7,13] .

In conclusion, this laboratory based survey report is believed to give an insight into the overall dynamics and the rate of *Salmonella* isolations in livestock and poultry in South Africa, and will provide an impetus for further investigation into the epidemiology and risk factors of salmonellosis in animals as well as the risk associated with human health.

ACKNOWLEDGEMENTS

We owe special debt of gratitude to Drs A Michel, A Potts and S Njiro for their encouragement, full support and reviewing of the manuscript.

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