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SALMONELLA ISOLATED FROM FEEDS AND FEED INGREDIENTS DURING THE PERIOD 1982–1988: ANIMAL AND PUBLIC HEALTH IMPLICATIONS

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ABSTRACT

DURAND, ANETTE M., GIESECKE, W. H., BARNARD, MARIE-LUISE, VAN DER WALT, MARTHA L. & STEYN, HELENA C., 1990. *Salmonella* isolated from feeds and feed ingredients during the period 1982–1988: Animal and public health implications. *Onderstepoort Journal of Veterinary Research*, 57, 175–181 (1990).

The prevalence of *Salmonella* in southern Africa in farm feeds and by-products of animal origin during 1982–1988 was determined.

Salmonella occurred in 5,18 % of the farm feed samples and in 9,54 % of the by-product samples. Different serovars were isolated, some only once. The findings underestimate the true prevalence of *Salmonella* in farm feeds and by-products, and is representative of only the most severely contaminated products.

The epidemiology of salmonellosis is discussed with special reference to the importance of multiple resistance to antibiotics, the increase in the number of cases of salmonellosis worldwide and "*Salmonella* free" feeds and foods.

More detailed research on the role of farm feeds in the epidemiology of salmonellosis is required. Efforts should be made to increase awareness of the problem, to improve quality management at farm feed production plants and to develop efficient systems to monitor the hygienic safety of feeds and foods.

INTRODUCTION

Africa is the continent with the fastest growing human population which, south of the Sahara, amounted during 1985 to 415 million people. The population is expected to increase to 840 million by the year 2005. In the year 2000, an estimated 42 % of this population will be living in urban areas (Sunter, 1987). In 1980, the Republic of South Africa (RSA) had a population of approximately 24,9 million. This population is expected to increase by the year 2000 to an estimated 45 million people (Joyce, 1987), predominantly living in urban areas.

The world population explosion and its concomitant urbanisation has serious implications relative to the economic production, storage, transport and distribution of food and farm feeds and the efficient monitoring of the hygienic quality and safety of such commodities. Three important aspects need particular attention; (i) optimal animal health to provide sufficient food of animal origin; (ii) monitoring of such food supplies by means of approved quality and safety programmes; (iii) reporting of food-borne diseases to facilitate an appropriate epidemiological follow-up. The importance of these aspects are endorsed by the concept of *healthy animals, safe food, healthy people* recommended by the World Association of Veterinary Food Hygienists (1989). Unfortunately, it apparently is not always appreciated under South African conditions that input costs of animal production and animal health depend to a large extent on the quality and safety of feeds ingested by food-producing livestock. Greater awareness of several important aspects of feed hygiene pointed out below is therefore required.

In the RSA, various farm feeds for food-producing animals are currently produced on an ever-increasing scale by farmers and commercial manufacturers. In 1985, 2 914 210 tons of feed mixtures were produced in the RSA. Bone meal production in the same year amounted to 27 716 tons (Directorate Agricultural Economic Trends, 1987). In view of the escalating demand for an extending range of farm feeds, as well as the regulations applicable to their chemical, nutritional, microbiological and other properties, it is important that organized agriculture and feed manufacturers deal with problems associated with the microbiological quality and safety of farm feeds.

Improved awareness of the subject of feed hygiene is essential because the hygienic quality and safety of farm feeds are integral aspects of the food chain extending from the animal production systems to the consumer. The microbiological quality of farm feeds can have major implications for the deterioration of the products during storage, their nutritional value and their effect on animal health and productivity and the profitability of animal production.

Feeds are favourable media for microbial growth, which can be further stimulated by environmental factors, such as elevated moisture and temperature. Deficient manufacturing practices and poor hygienic standards further attribute to undesirable contamination of animal feeds. Workers, birds, rodents and insects are the main source of spoilage and pathogenic micro-organisms, that can contaminate farm feeds.

Mossel (1977) has referred to the following 4 parameters which determine the pattern of microbial spoilage of human foods: (i) intrinsic factors; (ii) modifications in the composition of the food resulting from various ways of processing foods; (iii) extrinsic factors; and (iv) implicit factors. The same factors are also important to the colonization of a food by potentially pathogenic bacteria. Many similarities exist between the microbiological characteristics of human foods and farm feeds. On this basis it is proposed that the factors which affect growth of micro-organisms in human foods (Mossel, 1977) can be used as a model for farm feeds and can be described as follows:

Intrinsic factors: These include the water activity (= proportion of the water vapour pressure over a feed and the pressure of pure water at the same temperature), acidity and buffering capacity, redox potential and poising capacity (= resistance to a change in redox potential), type, amount and distribution of nutrients present, natural antimicrobial ac-

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tivities, as well as the physical structure. The water activity of feeds is probably the most important factor for stimulating or reducing microbial growth. Feeds with either a high water activity or high water content will deteriorate rapidly irrespective of their low initial microbial population. It can also be assumed that pH and redox potential can play an important role in stimulating or reducing microbial growth. Farm feeds are capable of sustaining microbial growth fairly well, because of their high concentration of different nutrients. Feed ingredients (meals of animal origin, plant materials and additives e.g. lipids, minerals) of inferior hygienic quality used in the production of feeds, can play a significant role in the initial bacterial load of the final product and contribute to the rapid spoilage of the feeds.

Modifications in the composition of a feed due to the metod of processing: Different processing methods such as heat treatment, irradiation, changes in the chemical composition and contamination during processing, can influence the pattern of microbial growth in feeds. The most important factor that usually changes the composition of a farm feed is the initial level of its microbial contamination. A high initial microbial count, with resultant growth, can bring about reduced levels of nutrients and increased levels of toxic metabolites and moisture. In contrast, heat treatment during the manufacture of certain feeds, such as pellets and canned pet foods, may reduce and even eliminate the microbial populations.

Extrinsic factors: These include storage temperature, water vapour pressure and the gaseous environment. The temperature at which feeds are stored is of great importance. Increased microbial growth can lead to further increases in the storage temperature. This can eventually stimulate more rapid growth of microbes and lead to a succession of microbial populations including increased fungal growth with a concomitant decrease in the quality of the product. Under these conditions physical characteristics of the feeds can be adversely affected. Other extrinsic factors of particular importance to feeds are rodents, insects, birds, workers and unhygienic practices (Giesecke, Barnard & Ogonowski, 1985).

Implicit factors: These are related to microbiological factors, such as specific rate of microbial growth, symbiosis and antagonism (Mossel, 1977), which can contribute to the development of different microbial populations in farm feeds. Proleferation of potential pathogens can be influenced by the presence of competitors in the microbial environment.

Feed hygiene has 2 main areas of interest: (1) hygienic quality (the prevention of spoilage caused by microbial activities); and (2) hygienic safety (the protection of animals, humans and the environment against feed-borne pathogenic micro-organisms which may affect animal and human health). The hygienic quality of feeds is affected when the nutrient level is reduced, moisture content and temperature are increased and palatibility and other characteristics are altered due to the influence of microbial contaminants in the feeds. Clumping, deterioration of pellets and bridge formation may occur during storage (Giesecke *et al.*, 1985). Such changes may have the following negative influences after ingestion by animals: reduced availability of nutrients, poor conversion of feed, reduced production and reproduction, reduced resistance to disease, and increased mortality (Giesecke *et al.*, 1985).

Microbiologically safe feeds are essential to protect animals, humans and the environment against feed-borne pathogens. The same conditions that influence the growth and spreading of spoilage bacteria can influence the growth and spreading in the environment of potential pathogens. Feeds containing potential pathogens, subjected to conditions promoting further bacterial growth, increase the risk of disease when fed to susceptible animals.

The salmonellae are of particular interest with regard to the microbiological safety of animal feeds and human foods (Mossel, 1977), and thereafter to the health of animals and humans (Acha & Szyfres, 1987). The genus *Salmonella* consists of a single species, *Salmonella enterica,* which contains more than 2 000 different serovars which are classified under 6 subspecies (Le Minor & Popoff, 1987). The subspecies are the following: (1) *S. enterica* subsp. *enterica* (found in warm-blooded animals; formerly subgenus I), (2) *S. enterica* subsp. *salamae* (isolated from the environment, cold-blooded animals and sometimes also from warm-blooded animals; formerly subgenus II), (3) *S. enterica* subsp. *arizonae* and *S. enterica* subsp. *diarizonae* (isolated from cold-blooded animals and poultry; formerly monophasic and diphasic members of subgenus III), (4) *S. enterica* subsp. *houtenae* (found in the environment and cold-blooded animals; formerly subgenus IV), (5) *S. enterica* subsp. *bongori* (isolated from cold-blooded animals) and (6) *S. enterica* subsp. *indica* (isolated from warm-blooded animals) (Ewing, 1986; Le Minor & Popoff, 1987).

The occurrence, prevalence, incidence, species-specificity, pathogenicity and virulence of the salmonellae depends on a range of factors. *Salmonella* infections other than those species-specific for man may be considered zoonoses. *Salmonella enterica* subsp. *enterica* ser. Typhi and *Salmonella enterica* subsp. *enterica* serovars Paratyphi A and Paratyphi C are specific to man, whereas *Salmonella enterica* subsp. *enterica* ser. Paratyphi B also can be found in cattle, swine, dogs and fowl. In contrast, *Salmonella enterica* subsp. *enterica* serovars Choleraesuis, Gallinarumpullorum, Abortusequi and Dublin are more adapted to animals, but are also transmissible to man. The presence of *Salmonella* serovars in feeds and human foods increases the risk of human salmonellosis, which is perhaps the most common zoonosis in the world (Acha & Szyfres, 1987).

According to Mossel (1977) *Salmonella* can spread from the environment to the food chain. A high carrier rate of *Salmonella* exists in healthy, food-producing animals, particularly in swine, calves and poultry, frequently exposed to foci such as insects, rodents, birds, contaminated feeds, surface water, sewage and effluent (Mossel, 1977). There is much evidence that certain *Salmonella* have a path of infection leading from farm feeds, through pigs and poultry, to pork and poultry products and, eventually, to man (Williams, 1975; Mason & Vines, 1986).

A number of factors are involved in the epidemiology of salmonellosis in animals and man, e.g. by-product meals, feed components, mixed feeds, water, farm and slaughter animals, abattoirs, by-products plants, transport facilities, waste water, meat, milk and dairy products (Giesecke *et al.*, 1985; Acha & Szyfres, 1987). Salmonellosis in humans is a food-borne disease that is normally triggered by comparatively large numbers of bacteria. The actual number of bacterial cells needed to cause the disease

depends on the *Salmonella* serovars present, the age and physical condition of the consumer, as well as whether inhibitory substances or conditions are present. According to Mossel (1977), the following *Salmonella* serovars are most commonly involved in human food-borne disease: *Salmonella enterica* subsp. *enterica* serovars Typhimurium, Panama, Stanley, Heidelberg, Brandenburg, Oranienburg, Newport and Derby. *Salmonella enterica* subsp. *enterica* ser.Thompson is also regarded as a causative agent of human salmonellosis (Acha & Szyfres, 1987).

Very little information is available concerning the microbiology of farm feeds produced in the RSA (Van den Heever & Van der Made, 1977; Van der Made, Van Staden, Du Toit, Jordaan, Barrett & Coetzee, 1980). An investigation is continuing under close collaboration with the Registrar of Act 36 of 1947 (Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act) and the Directorate of Animal Health. This paper presents the findings on *Salmonella* isolated from various animal feeds and feed ingredients during the years 1982 to 1988 of the ongoing investigation.

MATERIALS AND METHODS

Collection of samples

Samples of feeds, by-product meals and poultry litter were collected on routine inspection rounds of premises by qualified inspectors of the Registrar of Act 36 of 1947, as described by Ogonowski, Barnard & Giesecke (1984). The samples were taken during the loading of bulk carriers, from farm silos freshly filled with feed, and from bags.

Isolation of Salmonella *in the laboratory*

Salmonella were isolated by means of the method described by Ogonowski *et al.* (1984).

In March 1984 modified Rappaport-Vassiliadis (RV) enrichment medium (Vassiliadis, 1983; Vassiliadis, Kalapothaki, Trichopoulos, Mavromatti & Serie, 1981) was found to be more suitable than Selenite Brilliant Green Mannitol (SBM) broth (Ogonowski *et al.*, 1984) and was therefore incorporated into the laboratory routine as an additional isolation procedure; 0,1 mℓ of the incubated suspension was inoculated into 10 mℓ of RV medium and incubated for 24 h at 37 ± 1 °C. The rest of the isolation method remained unchanged.

Serotyping of Salmonella

Salmonella isolates were confirmed and serotyped as described by Ewing (1986), Le Minor (1984), Le Minor & Popoff (1987), Le Minor, Veron & Popoff (1982) and Parker (1983).

TABLE 1 *Salmonella* in farm feed samples for the period 1982–1988

Year	No. of samples investigated	No. of samples positive for *Salmonella*	% of samples positive for *Salmonella*
1	1 594	80	5,02
2	2 241	75	3,35
3	1 956	48	2,45
4	2 087	138	6,61
5	1 811	178	9,83
6	1 342	56	4,17
7	110	2	1,82
Total	11 141	577	5,18

RESULTS

Mixed farm feeds

The overall occurrence of *Salmonella*-positive samples among the 11 141 feed samples is given in Table 1.

Mixed farm feeds depending on target species

The different types of farm feeds examined and samples positive for *Salmonella* are given in Table 2.

By-products of animal origin

Table 3 depicts the overall occurrence of *Salmonella* in the by-product samples examined during the period 1982–1988. The percentage of by-product samples positve for *Salmonella* was higher than that of the farm feed samples examined.

TABLE 3 *Salmonella* in by-product samples for the period 1982–1988

Year	No. of samples investigated	No. of samples positive for *Salmonella*	% of samples positive for *Salmonella*
1	248	25	10,08
2	374	25	6,68
3	342	15	4,39
4	337	32	9,50
5	347	66	19,02
6	734	78	10,63
7	344	19	5,52
Total	2 726	260	9,54

Different types of by-products of animal origin

During the period of investigation, 1982–1988, the percentage of by-product samples positive for *Salmonella* varied from 2,86 % to 25,00 % depending on the type of by-product and year of investigation (Table 4).

TABLE 2 *Salmonella* in different farm feeds for the period 1982–1988

Year	Different farm feeds											
	Cattle		Calf		Pig		Sheep		Poultry		Miscellaneous	
	Number*	%+	Number*	%+	Number*	%+	Number*	%+	Number*	%+	Number*	%+
1	345	6,67	100	5,00	250	9,20	49	8,16	400	6,25	450	—
2	555	3,96	130	2,31	369	2,71	137	5,11	523	3,44	527	2,85
3	522	3,45	122	0,82	273	2,93	178	1,12	396	3,79	465	0,86
4	562	7,65	149	8,05	292	7,88	136	10,29	448	7,14	500	2,80
5	546	10,26	109	11,01	252	11,51	128	10,16	348	10,34	428	7,48
6	386	4,66	81	6,17	176	3,41	100	3,00	281	3,56	318	4,40
7	36	2,78	3	—	10	—	17	—	10	—	34	2,94
Total	2 952	6,13	694	5,48	1 622	6,10	745	5,77	2 406	5,65	2 722	2,94

* = Number of samples tested

%+ = Percentage of samples positive for *Salmonella*

TABLE 4 *Salmonella* isolated from different by-products for the period 1982–1988

Year	Different by-products													
	Carcase meal		Meat meal		Bone meal		Blood meal		Poultry manure**		Fish meal		Miscellaneous	
	Number*	%+	Number*	%+	Number*	%+	Number*	%+	Number*	%+	Number*	%+	Number*	%+
1	166	13,86	25	8,00	15	—	—	—	40	—	—	—	2	—
2	225	8,89	31	—	21	9,52	42	7,14	53	—	—	—	2	—
3	180	5,00	34	2,94	17	17,65	35	2,86	50	—	26	3,85	—	—
4	170	11,18	39	7,69	23	21,74	28	14,29	50	—	27	3,70	—	—
5	252	20,24	52	23,08	5	20,00	—	—	20	—	2	66,67	15	—
6	602	9,97	31	41,94	8	25,00	32	6,25	41	—	4	25,00	16	—
7	266	6,39	—	—	10	10,00	9	—	41	—	—	—	18	5,56
Total	1 861	10,69	212	14,62	99	14,14	146	6,85	295	—	60	8,33	53	1,89

* = Number of samples tested; **heat sterilized

%+ = Percentage of samples positive for *Salmonella*

TABLE 5 Number of *Salmonella* serovars isolated from feeds and by-products on an annual basis for the period 1982–1988

Serovar	Year						
	1	2	3	4	5	6	7
Samonella enterica subsp. *enterica*							
Agoueve	—	—	—	—	13*	5	—
Anatum	—	—	3	—	—	6	—
Anfo	—	2	—	—	—	—	—
Beaudesert	—	—	—	—	—	10	10
Bispebjerg	—	—	—	—	13	—	—
Bovismorbificans	2	—	—	—	—	—	—
Brazil	—	3	—	—	—	—	—
Cerro	—	—	—	—	10	—	—
Duval	—	—	—	4	8	—	—
Escanaba	12	—	15	—	—	—	—
Florida	—	—	—	4	—	—	—
Friedenau	—	—	—	7	—	—	—
Jacksonville	—	—	4	—	—	—	—
Jaja	3	2	—	—	—	—	—
Karamoja	2	—	—	—	—	—	—
Kouka	—	—	—	4	26	—	—
Kristianstad	—	—	—	—	28	—	—
Lexington	—	2	—	—	—	—	—
Macallen	—	—	—	37	—	—	—
Maiduguri	—	—	8	—	—	—	—
Marienthal	—	—	—	—	—	4	—
Memphis	—	5	—	—	—	—	—
Menston	—	—	—	—	6	—	—
Nawarre	—	—	7	—	—	—	—
Neumuenster	—	—	—	4	—	—	—
Newlands	—	—	—	—	6	—	—
Newington	—	—	3	—	—	—	—
Norwich	—	3	—	—	—	—	—
Oranienburg	—	—	—	8	—	4	—
Overchurch	—	—	—	—	9	—	—
Regent	—	—	—	—	—	7	—
Ried	—	—	—	—	—	4	—
Ruiru	—	—	—	—	7	—	—
Senftenberg	—	—	3	—	—	—	2
Singapore	4	—	—	—	—	—	—
Subero	—	—	—	—	10	—	—
Tafo	—	—	7	—	—	—	—
Thompson	38	30	10	28	—	—	—
Tinda	8	4	—	—	8	—	—
Tsevie	—	—	—	—	—	5	—
Typhimurium	—	—	—	—	—	10	—
Westerstede	6	4	—	—	—	—	—
Salmonella enterica subsp. *salamae*	—	—	—	9	38	8	—
Parow	—	—	—	12	—	—	—
Salmonella enterica subsp. *arizonae* + *diarizonae*	—	—	5	—	—	—	—
Salmonella rough	12	14	10	—	—	—	—

* = Number of isolates

Salmonella *serovars identified*

Table 5 indicates a great variation in the number and type of *Salmonella* serovars isolated. No clear pattern could be established relative to the isolation of specific serovars of *Salmonella,* in relation to specific types of feed or by-products and the year of investigation. A large number of serovars were only isolated once during the period of investigation (Table 5).

DISCUSSION

According to Stolle (1986), salmonellosis is the most important zoonosis associated with meat hygiene, foods of animal origin and human health. Heavily populated countries together with vast intensive food animal farming operations and the international trading in foods and feeds being facilitated by modern transport systems provide ideal conditions for the high prevalence of *Salmonella* in humans and animals on a worldwide basis. The situation in less developed countries is still unclear. Direct infection from animals to humans is not as important as the indirect transmission in a food, utensils and the environment. Meat, poultry, eggs, milk and their processed products have been established as a main mode of transmission of *Salmonella* to humans (Stolle, 1986).

Modern veterinary food hygiene, as part of public health, places particular emphasis on monitoring systems which promote three key elements, namely healthy animals, safe food and healthy people. It is apparent that the hygienic quality and safety of animal feeds are integral aspects of the human food chain extending from food-producing animal populations to the human consumer. These hygienic aspects are equally important to efforts aimed at improving herd health so as to optimize food animal production on a cost-effective basis.

In the light of the importance of animal feed hygiene it is disconcerting that the microbiological quality and safety of the animal feeds and by-products examined was so variable. The findings are consistent with results from earlier investigations by Van den Heever & Van der Made (1977) and Van der Made *et al.* (1980). There is clearly room for improvement in the quality management and manufacturing practices of the South African farm feed industry.

The isolation of *Salmonella* from 5,18 % and 9,54 % of the samples of mixed farm feeds (Tables 1 and 2) and by-products (Tables 3 and 4) respectively is regarded as being significant. The practical significance of such results may be doubted because of the low percentage of *Salmonella* positive samples, the range and frequency of *Salmonella* serovars isolated (Table 5) and the inconsistency of their isolation during the 7 years of investigation. It is felt that the number of *Salmonella* positive samples in this study (Tables 1–4) does not depict the true prevalence of *Salmonella* in farm feeds and by-products in the RSA. Only heavily contaminated products can be expected to yield positive isolations and the occurrence of *Salmonella* in these products is probably much higher.

Under field conditions it is sometimes difficult to obtain representative samples of farm feeds and by-products because of factors such as the amount, packing, storage, consistency, admixture and composition of the batch of product available for sampling. In addition other difficulties occur during the laboratory processing of samples (e.g. homogenous mixing of sample material and size of inoculum for initial culturing in enrichment medium). For these reasons *Salmonella* negative results do not preclude the presence of *Salmonella* in portions of the product consignment.

The findings of this extensive investigation suggest that the reliability of the microbiological screening of feeds and by-products can be increased by more frequent examinations of more and larger samples. However, a more cost-effective method for such routine screening needs to be worked out. Despite its limitations, the present method seems sufficiently practical and economical to identify the worst cases of contamination, draw attention to the major problems associated with the microbiological safety of feeds and by-products and to promote efforts at improving the present situation.

It is clear that no persistent pattern in the isolation of *Salmonella* from different farms feeds could be established during the period of investigation (Table 1). In 1985, a higher percentage of samples tested positive for *Salmonella.* No apparent reason for this result could be found. Miscellaneous feeds tend to show a comparatively low prevalence of *Salmonella* (Table 2) apparently because of the inclusion of canned pet foods that are heat-treated during the canning process. No persistent pattern for the isolation of *Salmonella* from by-products during the period of investigation could be established (Tables 3 and 4).

Human salmonellosis is not a notifiable disease in the RSA. The role of farm feeds in the epidemiology of human salmonellosis in southern Africa is not known and the actual prevalence of salmonellosis has not been established.

The need for the overall improvement of hygiene during the manufacture of farm feeds and by-products is further underlined by the range of *Salmonella* serovars identified (Table 5). Many of these serovars have also been isolated in the RSA from human patients (Giesecke *et al.*, 1985). Irrespective of the range and variation of the *Salmonella* isolated (Table 5), the presence of *Salmonella* in feeds and by-products contribute to the complex epidemiology of salmonellosis and increases the risk of human infection and therefore the importance of the organism to public health.

An additional potential problem of human salmonellosis is the number of *Salmonella* isolated from farm feeds that show multiple resistance to antibiotic drugs (Durand, Barnard, Swanepoel & Engelbrecht, 1987; O'Brien, Hopkins, Gilleece, Medeiros, Kent, Blackburn, Holmes, Reardon, Vergeront, Schell, Christenson, Bissett & Morse, 1982; Spika, Waterman, Soo Hoo, St. Louis, Pacer, James, Bissett, Mayer, Chiu, Hall, Greene, Potter, Cohen & Blake, 1987). Acha & Szyfres (1987) have emphasized this danger by stating . . . "In the last 2 decades, a high proportion of *Salmonella* with multiple antibiotic resistance has been seen in many countries. The main cause of this phenomenon in industrialized countries has been the excessive use of antibiotics in animal feeds as growth enhancers, and also the indiscriminate prescription-drug treatment of people and animals."

Problems related to *Salmonella* are increasing in Europe, the United Kingdom and United States of America. Concern about the presence of *Salmonella* in farm feeds is growing, especially because of the role that these organisms can play in contaminating the environment, entering the human food chain and the transfer of antibiotic resistance to non-resistant serovars. Outbreaks of food poisoning in the United Kingdom were traced to eggs contaminated with *Salmonella enterica* subsp. *enterica* ser. Enteritidis phage type 4. It was thought that this particular *Salmonella* entered the country by means of imported contaminated poultry feeds (Mason & Vines, 1986). It seems that environmental factors linked with animal husbandry systems, farm feeds and fertilisers, contamination of pastures, water-

borne infections, human and animal carriers and housing factors may play a more important role in the dissemination of salmonellae than originally thought (Williams, 1975).

The notification of human cases of salmonellosis in Australia is increasing. A total of 431 cases were reported in 1985, 514 in 1986, 666 in 1987 and 441 in the first 6 months of 1988. The cause for the increase has not been established despite the monitoring of food standards and the surveillance of food handling practices (Livingstone, 1988).

By using restriction-endonuclease digestion O'Brien *et al.* (1982) showed that identical or nearly identical antibiotic-resistant plasmids may be found in salmonellae isolated from animals or persons in different parts of the USA. By analysing plasmids of resistant strains, Spika *et al.* (1987) traced the source of chloramphenicol-resistant *Salmonella* ser. Newport from hamburgers to dairy farms. Ground beef obtained from slaughtered dairy cows was apparently the vehicle which transmitted this *Salmonella* serovar. This serovar was traced microbiologically as well as epidemiologically from an outbreak of salmonellosis in consumers to meat processors, abattoirs and farms from which animals were sent for slaughter. These investigations indicate that animal isolates of *Salmonella* were spread to humans through contaminated food products (Spika *et al.*, 1987).

Legislation in the United Kingdom requires that the protein component of animal feeds be "*Salmonella* free". This action was taken because feed producers started adding animal protein to what was formerly a mix of grain and mineral concentrates. A new code of practice is being proposed in which the government recommends that farmers take steps to improve hygiene in poultry houses and clean them between batches. Producers should monitor feeds and hatcheries for bacteriological contamination and improve hygiene during transport and egg collection. Imported animal proteins are also required to be "*Salmonella* free" (Mason & Vines, 1986).

Possible measures to prevent salmonellosis and the dissemination of *Salmonella* through the food chain and environment include keeping the initial number of *Salmonella* bacteria in feeds and foods as low as possible and making use of hazard analysis of critical control points (HACCP) from the primary product throughout further processing. The emphasis on "*Salmonella* free" feeds and foods in Europe, Canada and the USA is a significant step in trying to achieve this aim. The consumer should be made aware of the dangers involved in consuming contaminated food products. Preventive measures in food preparation e.g. proper heating and cooking, should also be brought to the attention of the consumer. This is of importance especially in rural areas of South Africa.

In the light of the results of this investigation, the data on isolation of *Salmonella* from animals and humans in southern Africa (Giesecke *et al.*, 1985), the resistance of *Salmonella* to various antibiotics (Durand *et al.*, 1987), and the potential spreading internationally of *Salmonella* by consignments of animal products, it is apparent that efforts are required in the South African farm feed industry, to improve the control of *Salmonella* contamination in feeds.

CONCLUSIONS

This work confirms the need for more detailed research concerning the role of farm feeds in the epidemiology of salmonellosis. Efforts should be made to increase awareness of the problems associated with *Salmonella* in general and to improve quality management at feed plants. Surveillance systems which promote efficient monitoring of programmes concerning the quality and safety of feeds and foods need to be optimised. Such surveillance programmes should be aimed at improving the microbiological quality and safety of all mixed animal feeds and feed ingredients, with particular emphasis on the safety of by-products of animal origin. Only in this way the demand for safe, high-quality food supplies of the increasingly urbanized growing population of southern Africa can be met.

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