SALMONELLA IN MEAT PRODUCTS

by
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Livestock have long been recognized as one of the most important reservoirs of salmonellae (Rankin et al., 1970; McCaughey et al., 1971). The organisms reside primarily in the intestines and on the hides, skins and feet of the animals.

Carcass Contamination

Bacterial contamination is spread from the skin to the carcass surfaces and to the meat during slaughtering and dressing operations by: (a) contact between the outer surface of the skin and the carcass; (b) transfer onto the hands, knives and other equipment, and (c) passage through the air (Ayres, 1955). Seldom are salmonellae indigenous to edible tissues of apparently healthy animals. When such animals are moved from the producer to the processing plant, resident salmonellae may be carried into the slaughtering plant and subsequently transferred to the meat during the preparation of the carcass (Shotts et al., 1961; Fomin and Simmons, 1972). Salmonellae present in lymph and mesenteric glands (Hormaeche and Salsamendi, 1939; Ruben et al., 1941) and in lymph nodes not removed from the carcass, also may contribute to the incidence of these organisms in meats (Kampelmacher et al., 1965; Tompkin, 1975).

When animals are held for a time before slaughter, salmonellae from diverse sources may be brought together (Bryan et al., 1969). Table 1 shows the results of examination of mesenteric glands from pigs held for short and for long periods and demonstrates the increase in infection in pigs kept in contaminated holding pens for longer than 1 to 2 weeks.

The table also shows that a very small proportion of pigs arriving from various areas were infected with S. *brandenburg* indicating a widespread endemicity rather than a focus of infection. Holding animals in pens for long periods is conducive to a build-up of pathogens. A marked increase in the number of isolations of S. *brandenburg* was observed by Hobbs (1965) (see Table 1). Three months after this organism was initially isolated from a factory lot of pork sausage meat, 11 to 17 percent of samples of pork and beef sausage meat from two factories receiving carcasses from the same suppliers were contaminated with S. *brandenburg*. Samples of chopped beef and pork meat from two other factories showed that 3.6 percent and at least 15 percent, respectively, were contaminated with salmonellae but not S. *brandenburg*. Sausages of the same brand from retail shops were examined two months later and 23 percent of approximately 90 samples were positive. When meat and skin scrapings from pig carcasses from 12 suppliers were examined, only carcasses from one supplier were positive for S. *brandenburg* on three occasions. In the slaughter house concerned, pigs were kept in a number of holding pens for periods from 1 day to 1 to 3 months.

Isolation of S. *brandenburg* from the holding pens were rare after the pens had been thoroughly cleaned and used for pigs killed as soon as possible after purchase.

At the time of slaughter, salmonellae appear to be prevalent. In 1969, Weissman and Carpenter (1969), reported a high incidence of positive results when they swabbed large surface areas of 50 hogs from 5 plants in Georgia (Table 2). Surkiewicz et al. (1972) reported recovering salmonellae from five of 36 eviscerated hog carcasses from 29 plants.

Despite the myriad opportunities that salmonellae have for grossly contaminating carcass meats, relatively few of these pathogens have been recovered from fresh beef.

According to a review reported by Tompkin (1975), data from the U.S. and Canada since 1960 show that the incidence of salmonella contamination in fresh beef seldom exceeds 0.8%. Information from ten separate investigations during the period 1972-1977 and involving 1228 samples shows a relatively low incidence of salmonellae in beef products (Table 3). Among all samplings, 34 or $< 2.8\%$ were salmonellae-positive and in half of the investigations no salmonellae were recovered from any of 1228 samples analyzed.

When a special tube method (Harper and Shortridge, 1969) was used for isolating salmonellae, Fomin and Simmons (1972) recovered the organisms from 16 of 92 meat samples as contrasted with 2 positives

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TABLE 1

SALMONELLAE FROM PIG MESENTERIC GLANDS IN RELATION TO CONTAMINATION OF HOLDING PEN AND LENGTH OF STAY OF PIGS IN HOLDING PENS (ADAPTED FROM HOBBS, 1965)

Holding Pen No.	Salmonella Contam. of Holding Pen	No. of Pigs Exam.	Salmonella + Pigs No.	Salmonella + Pigs %	Serotypes Isolated	Length of Stay in Holding Pen
3	—	19	2	10.5	**brandenburg typhimurium**	Short
6	—	19	1	5.3	**brandenburg**	Short
5	+	19	6	31.6	**brandenburg**	Long
7	+	11	10	90.9	**brandenburg typhimurium** (5 each)	Long

by the broth-agar method. Also, in one of the studies (Manickam and Victor, 1975), with Indian cattle, large areas of the carcass were sampled, i.e., swabs were taken from the entire rump, flank, foreleg or peritoneal regions. Salmonellae were recovered from only 4 of 67 animals. Positive findings were less common in the remaining studies wherein more conventional sampling procedures were utilized.

Trimmed Meats

A Canadian survey (Anon., 1974b) indicated that only 18 of 897 samples (2%) of ground beef and beef patties were positive for salmonellae. During the same year, in a survey conducted by workers at the University of Guelph (Anon., 1974c), no samples were reported to contain any salmonellae.

From 1972 to 1975 the USDA (Anon., 1975) intermittently surveyed raw ground beef patties. In these surveys, only 1 of 690 samples (0.14%) of raw trimmings tested and 3 of 735 finished patties (0.4%) were found to be salmonella-positive. According to Goepfert and Kim (1975), these organisms are unable to proliferate in adequately refrigerated ground beef since (1) the temperature of storage is subminimal for growth, (2) the organisms must compete with the normal flora of meat and (3) continuous low temperature results in a pronounced loss of viability.

Hobbs (1965) cited data from boneless beef samplings prepared by different meat establishments in Argentina (Table 4). Her results indicated that contaminated samples were obtained from almost 70% of the slaughter plants. More than one-fifth of the 1326 samples examined (22.3%) were positive for salmonellae. It is likely that during the boning operation, salmonellae of human origin were introduced, that multiplication of these contaminants occurred if the carcass or meat was not continuously maintained at low temperature and/or that salmonellae already present were further disseminated during the additional handling that the meat received.

Weissman and Carpenter (1969) isolated salmonellae at low levels (i.e. > 80% were positive only in 25 g portions) from 28% of 529 samples of pork trimmings used for sausages and an equal percentage from 560 finished samples. Later, Carpenter et al. (1973) found salmonellae (Table 5) on 52 of 221 (23.3%) hog carcasses from one of four abattoirs (Abattoir A). These results contrasted to earlier findings reported by Weissman and Carpenter (1969) wherein salmonellae were recovered from each of five plants checked. In the later study, none of these organisms were recovered from Abattoirs B, C, and D although 100, 65 and 34 carcasses, respectively, were examined. The researchers indicated that Abattoirs B, C and D were receiving hogs from geographic areas different from those of Abattoir A.

TABLE 2

INCIDENCE OF POSITIVE CULTURES OF SALMONELLA IN HOG CARCASSES (WEISSMAN AND CARPENTER, 1969)

Abattoir	Hog Carcass Cultured	No. Positive
1	18	8
2	3	1
3	13	11
4	6	6
5	10	2

TABLE 3

RECENT REPORTS OF SAMPLINGS OF BEEF FOR CONTAMINATION BY SALMONELLAE

Investigator(s)	Date Reported	Total No. of Samples	No. Having Salmonellae	% Contamination
Childers et al.	1973	93	0	0
Duitschaever et al.	1973	213	0	0
Field et al.	1977	112	3	3
Fomin and Simmons	1972	92	16	18
Foster et al.	1977	150	0	0
Ladiges and Foster	1974	100	0	0
Manickam and Victor	1975	67	4	6
Pivnick et al.	1976	218	8	4
Smith et al.	1976	112	3	3
USGAO (Fed. Reg.)	1974	71	0	0
Total:		1228	34	2.8

TABLE 4

SALMONELLAE IN BONELESS BEEF FROM DIFFERENT MEAT ESTABLISHMENTS IN ARGENTINA, 1961-1963 (HOBBS, 1965)

Establishment Number	Year	Number of Samples Examined	Positive for Salmonellae	
			Number	Percent
1	1963	12	0	0
1a	1963	45	1	2.2
2	1963	62	10	16.2
3	1963	25	0	0
7	1963	27	0	0
8	1963	11	5	45.4
12	1961	5	0	0
20	1963	66	17	25.7
25	1963	45	22	48.9
44	1963	121	1	0.8
66	1963	141	32	22.7
1383	1961	25	0	0
	1963	226	88	38.9
1404	1961	10	2	20.0
	1963	152	39	25.6
1464	1961	5	0	0
1930	1963	196	4	2.0
1979	1963	62	25	40.3
1985	1963	90	50	55.5

Vacuum Packaging

The trend of the industry is toward centralized vacuum-packaged primal and subprimal cuts in order to extend shelf life by inhibiting the growth of pseudomonads and similar spoilage-type bacteria. At present about two-thirds of all beef shipped from processing plants in the United States is vacuum-packaged. Salmonellae may survive for as long as six weeks when vacuum-packaged or traditionally stored meats are held at 0-2 C (32-35 F), but die slowly when the temperature is maintained at 5.6 C (42 F) or less (Table 6).

In fact, Deibel and Goepfert (1977) and Goodfellow et al. (1977) indicate no public health hazard from vacuum-packaged or traditionally wrapped meats if the holding temperature does not exceed 10 C (50 F). Other investigations (Davidson and Witty, 1977; Goepfert and Kim, 1975) show that salmonellae can grow in meat when holding temperatures are excessive, i.e. 12-12.5 C (53.6-54.5 F). Yet even at these temperatures, growth of spoilage flora is still faster. No data shows that salmonellae grow any more luxuriantly or at a faster rate in vacuum-packaged beef than in traditionally wrapped meats. Indeed, while salmonellae are facultative organisms, they are able to grow better under aerobic than under anaerobic conditions. Therefore, vacuum packaging tends to restrict their growth – not stimulate it.

The organisms which predominate on vacuum-packaged meats are lactic acid formers as opposed to the typical pattern of *Pseudomonas-Achromobacter*

TABLE 5

RECOVERY OF SALMONELLAE FROM PORK CARCASSES FROM ABATTOIR A (FROM CARPENTER *et al.*, 1973)

Day	Carcasses Examined	Salmonella Incidence
1	10	0
2	20	8
3	20	7
4	40	19
5	40	3
6	24	4
7	25	3
8	17	4
9	25	4
Total	221	52 (23.3%)

TABLE 6

RECENT REPORTS OF CRITICAL TEMPERATURE(S) AT WHICH SALMONELLAE GROW OR DIE GRADUALLY IN REFRIGERATED, PACKAGED GROUND BEEF

Investigator(s)	Date	Temperature °C	Temperature °F	Growth	Gradual Destruction (+)
Patterson and Gibbs	1977	0-2	32-35.6	—	+
Goepfert and Kim	1975	0.6	33	—	+
Brown	1977	1.1	34	—	+
Kennedy and Oblinger	Personal Commun.	1.7	35	—	+
Goodfellow **et al.**	1977	1.7	35	—	+
Deibel and Goepfert	1977	4.4	40	—	+
Goepfert and Kim	1975	4.5	40.1	—	—*
Brown	1977	5.6	42	—	+
Goepfert and Kim	1975	7	44.6	—	—*
Deibel and Goepfert	1977	10	50	—	+
Goodfellow **et al.**	1977	10	50	+	+**
Davidson and Witty	1977	12	53.6	+	
Goepfert and Kim	1975	12.5	54.5	+	

*Neither growth nor destruction noted.

**Slight growth followed by gradual destruction.

(*Moraxella-Acinetobacter*) which prevails on traditionally wrapped meats. Lactics poise the meat at a more acidic pH and the antimicrobic metabolites they elaborate (Kafel and Ayres, 1969) are inhibitory to competing microorganisms; therefore, under anaerobiosis, growth of extraneous flora, including salmonellae, is less rapid. The growth of lactic acid organisms is favored also by low temperatures (0-4 C; 32-40 F) characteristic of holding temperatures from vacuum-packaged beef. Thus a preservative system is set up which prevents the growth of salmonellae and food spoilage microorganisms. The selective environment extends the storage stability of vacuum-packaged products over that of the non-vacuum packaged.

No evidence supports the contention that salmonellae or other bacteria bathe the surface and migrate along the membranes connecting intact muscle tissue. Thomas (1966) and Gill and Penney (1977) report no penetration of bacteria into organoleptically sound meat should occur.

Retail Meats

Data from 21 to 26 samples of raw meats procured from local retail markets each week for a six week period indicated that the percentage of lots positive for salmonellae ranged from 12.5 to 19.2% on a weekly basis (Table 7). The percentage of contaminated samples remained fairly constant throughout the period, as was demonstrated by a mean incidence of 14.8%. Among the three types of meat analyzed, the percentage of pork samples contaminated by salmonella was highest (21.5%), beef was intermediate (11.1%) and poultry was lowest (7.3%) (Table 8). These results contrasted with earlier findings (Anon., 1974a) of the U.S. Food and Drug Administration. Their report on 100 raw poultry and 100 raw meat samples obtained from 20 retail stores in each of ten metropolitan areas indicated that 31% of the poultry samples and 17% of the meat samples were contaminated by salmonellae.

TABLE 7

INCIDENCE OF SALMONELLAE IN RETAIL MEATS PURCHASED DURING A SIX WEEK PERIOD
(adopted from Swaminathan et al., 1978)

Week Starting	No. of Samples	No. Salmonella Positive	% Contaminated
4-5-77	22	3	13.6
4-12-77	21	3	14.2
4-25-77	26	5	19.2
5-9-77	24	3	12.5
5-16-77	25	4	16.0
5-23-77	24	3	12.5
Total:	142	21	14.8

TABLE 8

INCIDENCE OF SALMONELLAE IN RETAIL SAMPLES OF PORK, BEEF AND POULTRY
(adapted from Swaminathan et al., 1978)

Type of Product	No. of Samples	No. Salmonella Positive	% Contaminated
Pork	65	14	21.5
Beef	36	4	11.1
Poultry	41	3	7.3
Total:	142	21	14.8

A comparison of the extent of contamination by salmonellae of meats obtained from five retail outlets is shown in Table 9. The incidence of contamination was much lower in one of three national supermarkets (8.3%) and in a regional supermarket (8.8%) than in a local grocery and meat store (16.7%) or in the other two national supermarkets (22.7 and 23.1%).

The national supermarkets displayed their meats and poultry samples in pre-packaged condition in refrigerated display cabinets. The meats for the three national chain stores were packaged at centralized packaging facilities located outside the Athens area. Meats sold at the regional supermarket, at the local grocery and meat store were not pre-packaged. Instead, the meats were displayed on stainless steel trays in a refrigerated display cabinet. When customers requested a particular meat, the salesperson transferred the desired quantity of the chosen meat by hand, determined the weight, and wrapped the meat in Kraft paper. Poultry products sold at these outlets, however, were pre-packaged in styrofoam trays and wrapped with cellophane paper.

Since the maximum incidence of contamination by salmonellae occurred in pork, the data on pork samples obtained from different sources were re-grouped as shown in Table 10. Pork samples constituted 45 to 61% of all samples purchased from four of the retail outlets but only 20.6% of the samples purchased from the regional supermarket. Except for one national supermarket (NAT 2), the contamination level of pork samples ranged from 25 to 30.8% from all outlets. It is noteworthy that the percentage of salmonellae in pork samples purchased from that market (NAT 2) was only 5.8%, although pork represented 52.7% of all samples purchased from that outlet. The three national supermarkets procured the fresh pork sausage

TABLE 9

INCIDENCE OF SALMONELLAE IN MEATS OBTAINED FROM VARIOUS RETAIL OUTLETS (Swaminathan et al., 1978)

Retail Outlet	No. of Samples	No. Salmonella Positive	% Contaminated
NAT 1	22	5	22.7
NAT 2	36	3	8.3
NAT 3	26	6	23.1
LOC	24	4	16.7
REG	34	3	8.8

NAT = National Supermarket
REG = Regional Supermarket
LOC = Local Grocery and Meat Store

they sold in prepared and pre-packaged form from meat packing companies – the chain store acted only as the retailer for these products. In contrast to this, all the pork sausage obtained from the regional and local stores was freshly ground and was packaged at the store. The 21 samples of pre-packaged pork showed a contamination level of 19.0%, while the 13 samples of freshly prepared pork sausage had a 38.5% incidence of salmonellae. The high level of contamination coincides with that reported by Weissman and Carpenter (1969) for this type of product (Table 11). Further, these findings are consistent with data reported earlier by Galton *et al.* (1954) and by Wilson *et al.* (1962).

Since an appreciable portion of fresh pork sausage samples purchased from retail outlets are contaminated with salmonellae, the need for the proper handling and storage of such meats in the home should be stressed. Even if all the precautions of proper storage and cooking of these meats at temperatures high enough to destroy the organism are taken, the likelihood of transmitting viable salmonellae from contaminated sausage to uncooked foods remains a public health problem of considerable significance.

To have maximal protective effect, it is essential that the meat be maintained at low temperature from the time that the animal is slaughtered until it is used by the consumer. In the U.S., packers are required to chill carcasses promptly to 2-3 C (35.5-37 F) and offal to 1 C (34 F); cutting and boning rooms must operate at 10 C (50 F), and packing and shipping rooms at 10 C (50 F) or less. Often, such careful temperature control is not enforced during transportation to the retailer or in retail display cabinets (Duitschaever, 1975). Duitschaever found that the temperature of about 80% of retail meat cabinets checked ranged from 10 to 15 C (50 to 59 F). Another study (Pivnick *et al.*, 1975) indicated that over half of the display cases surveyed (51.2%) were held over 4 C.

Summary and Conclusions

While salmonellae occur in association with meat animals, numerous investigations indicate that overt contamination of fresh beef by these organisms does not occur. Incidence of contamination varies with degree of sanitation, holding temperature, type of product, and size of sample tested.

A high surface count of bacteria does not necessar-

TABLE 10

INCIDENCE OF SALMONELLAE IN PORK SAMPLES OBTAINED FROM DIFFERENT OUTLETS (SWAMINATHAN et al., 1978)

Retail Outlet	Total Samples	Pork Samples	% Samples	No. Contam.	% Contam.
NAT 1	22	10	45.4	3	30.0
NAT 2	36	19	52.7	1	5.3
NAT 3	26	16	61.5	4	25.0
LOC	24	13	54.2	4	30.8
REG	34	7	20.6	2	28.6

NAT = National Supermarket
REG = Regional Supermarket Chain
LOC = Local Grocery and Meat Store

TABLE 11

INCIDENCE OF SALMONELLA IN FRESH, SMOKED, AND PROCESSED MEAT SAMPLES (Weissman and Carpenter, 1969)

Product	No. Examined	No. Positive	Incidence (%)
Fresh pork sausage	81	31	38.3
Smoked pork sausage	11	1	9.0
Frankfurters	8	0	0
Smoked link sausage	9	0	0
Miscellaneous sausage products	16	1 (Souse)	6.2

ily mean proportionately high numbers of salmonellae. Unless meat has begun to spoil or has been treated with a proteolytic enzyme, these organisms do not penetrate to the interior.

Vacuum-packaging markedly extends shelf-life by the exclusion of air to retard the growth of pseudomonads, other spoilage organisms and pathogens – particularly that of the facultatively anaerobic salmonellae. At the same time, vacuum-packaging favors growth of lactic acid-forming bacteria so that after four weeks of refrigerated storage, vacuum-packaged beef may have in excess of 10 million such cells/gram. The slightly acid media these organisms produce and the metabolites they release further retard proliferation of undesirable organisms. Meat juice which forms on the surface of vacuum-packaged beef is inhibitory to most pathogens.

The outbreaks of salmonellosis which do occur usually result from improper handling and cooking by the retailer and housewife – not from prior contamination of meat. This is evident from details of salmonellosis outbreaks traced to meat occurring in the past few years as described in *Morbidity and Mortality Weekly Reports*. However, the Center for Disease Control does not have evidence associating outbreaks of salmonellosis with vacuum-packaged fresh beef.

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