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SALMONELLOSIS

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TABLE OF CONTENTS

As a whole, the Salmonella group of organisms is associated with animals, domestic as well as wild, and animal passage alone suffices for the perpetuation of species. The infected animal kingdom acts as the natural reservoir and forms the basis of continual existence of the agents. Transmission to man is a biological possibility but not a biological necessity.

In accordance with this concept, contaminated animal materials are the primary source of human salmonellosis. Transmission takes place by direct or indirect contacts with such materials while human cases may create additional sources for secondary cases.

I INCIDENCE OF HUMAN SALMONELLOSIS

Reporting of human salmonellosis is very incomplete because of inadequate diagnostic facilities. In Denmark for instance, a nation-wide typhi-murium epidemic in August 1955, totalling more than 10,000 cases produced only 721 bacteriologically confirmed cases for official reporting. The vehicle of infection was a certain brand of mayonnaise-salad advertised and sold all over the country. Examples of official statistics are given in the following table:

Human salmonellosis

	Reported sporadic cases and outbreaks		
Denmark	1947-57		4433
England and Wales	1949-57		27588
USA	1953-57		116
Italy	1952-56	ca.	200
Poland	1952-57		141
Switzerland	1952-58		961
Holland	1950-58	ca.	12000
West Germany	1953-57	ca.	16500

It seems a safe conclusion that many countries have not yet realized the true magnitude of their salmonella-problem.

Incidence of human salmonella-excreters

			Excreters per 1000
England	1954	10,000 persons	2.4
Poland, Poznan	1959	7,210 "	2.2
" Lodz	1959	39,921 "	4.1

II INCIDENCE OF ANIMAL SALMONELLOSIS

Bacteriological examination of dead animals

Sweden (total about 67,000)

(Thal, Rutquist & Holmquist)

Animal species	Per cent 1949-56	Salmonella-positive 1956-57
Horses, adult	0.25	0.28
Foals	1 37	0
Cattle, adult	0 25	1.68
Calves	1.20	2.95
Pigs	1.66	3.26
Sheep and goats	0.86	1.32
Poultry (exclusively S.pullorum-gallinarum)	0.19	7.47
Chicken	1 30	21.99
Dogs	0.66	1.09
Cats	1.03	4.35
Fur-animals	3.75	0.79
Bird pets		4.17
Other animals	2.01	1.00

Incidence of salmonella excreters among normal slaughter animals

Country	Year	Species	Total examined	Excreters per 1000
England	1950-53	cattle	ab. 4,000	44
"	1940-47	pigs	6,285	27
USA	1954	pigs	374	70
Sweden	1953	cattle	1,210	0.8
"	1953	calves	6,348	14.6
"	1953	pigs	9,278	8.3
"	1954	cattle, calves, pigs	53,696	6.6
"	1954	" " "	51,000	1.5
Norway	1957	pigs	4,114	103
"	1957	cattle	410	24
Denmark	1958	pigs	9,693	4.2
"	1959	poultry	2,835	3
"	1959	seagulls	307	50

Incidence of salmonella in imported foods.

Food	Country of examination	No. samples	Per cent positive
Dried whole egg	England	1601	8
Frozen " "	"	8962	8
Dried egg white	"	5581	19
Frozen " "	"	2681	12
Frozen whole egg	Germany	791	8.7
Frozen deboned veal	Sweden	1000	9
Raw pork sausages	USA	217	23
Smoked pork sausages	"	127	12.5

Incidence of salmonella in imported animal feed

Feedstuff	Country of examination	No. samples	Per cent positive
Meat and bonemeal	Sweden	515	26.6
" " "	Denmark	329	3
Fishmeal	Germany	270	15
Oil seed cakes	Norway	910	4.6
" " "	Denmark	72	10

III THE EPIDEMIOLOGY OF HUMAN SALMONELLOSIS

Human salmonellosis is nearly always foodborne. A few cases may develop from direct contact with infected animals or humans. The food must contain an infective level of living invasive organisms. Animals, as well as man, seem to contract the clinical disease only when massive doses are involved, provided their resistance is not below normal for some reason or other (infants, old age, malnutrition). Ingestion of slightly contaminated foods in healthy individuals normally will produce latent infections only accompanied by transient excretion of bacilli. The infected animal population is the main source of food contamination and faecal pollution the main medium of contamination.

Types of foods acting as vehicles of infection

These may be seen from the following statistics.

Foods identified in 485 outbreaks of salmonellosis in England and Wales

(Cockburn, 1954)

Fish products and shell-fish	4.3 per cent
Fresh meat and prepared meat foods	43 "
Sweets (custard, egg cream, icecream)	15 "
Egg	28.7 "
Milk	3.7 "
Other foods (fruits, vegetables, cheese)	5 "

From these figures, meat and eggs emerge as the important sources. On the assumption that sweets mainly contract the infection from eggs, dishes with eggs attain the same percentage as meat-dishes, namely 43 per cent, and altogether the two categories account for 86 per cent of the total number of outbreaks.

In some parts of the world, foodstuffs, other than meat and eggs, may play an important role. Reports from Japan incriminate fish and shell-fish as the most frequent source which is relevant to the very high consumption of such food by the Japanese population, while the consumption of meat is low.

IV MEAT-BORNE SALMONELLOSIS

When salmonella are present in meats this may be due either to intra-vital septic salmonellosis in food animals or to post-slaughter surface contamination from animal or human intestinal excreters. Which is more important depends upon the state of development of the meat trade. In some countries and localities, the meat trade is almost entirely a business of fresh meat, which is slaughtered and sold locally in the form of fresh cuts of meat. There are no long distance transports of meats, no meat preservation practices and manufacturing of preserved or half-preserved meat products. In its most marked form this type of meat trade is found in many American, African and Asiatic countries covering very large areas of the world's tropical and sub-tropical zones. A hot climate coupled with the absence of refrigeration facilities or other technical methods of preservation are the natural circumstances which have led to the traditional practice of daily slaughter for one day's consumption only. The storage life of meat is not more than

twenty-four hours, and when meat has to be stored, it is stored in the form of live animals. The slaughter-houses are based upon a limited local market. Slaughter takes place regularly every day early in the morning, and before the end of the day (usually even before noon) all of the day's volume of meat and edible viscera has been sold and consumed. An important characteristic of this system of meat marketing is the very strong consumers' preference for freshly slaughtered meat. This preference is based upon customary opinions on taste and quality which are quite different from those generally held in temperate zones, where consumers prefer to have their meat ripened.

In some other countries and localities, especially covering the temperate zones of the world and areas with an advanced industrial economy, the meat trade and the meat industry are carried on in quite a different way. If the former type of meat trade may be termed the agricultural type, this type may be named the industrial type. The characteristics of this type of organization are centralization of slaughter at industrial plants, extensive application of refrigeration, long-distance transportation of meat and a large-scale production and consumption of preserved and half-preserved meat products.

In countries having an agricultural type of meat trade, meat-borne salmonellosis due to slaughter of animals affected by septic salmonellosis is common. Either the diseased animals are killed illegally or the condition is not discovered because of inadequate meat inspection systems. This type of meat-borne salmonellosis, giving rise to explosive localized epidemic outbreaks involving large numbers of people, was classic in Germany and other European countries before the development of meat inspection in the last decades of the nineteenth century.

On the other hand in countries having an industrialized type of meat trade secondary in-slaughter and post-slaughter surface contamination has acquired much more importance, while pre-slaughter infection has become of very rare occurrence as a source of meat-borne salmonellosis. Efficient meat inspection systems prevent illegal slaughter and diseased or suspect animals are withheld, but at the same time the development of a centralized and complicated industrial trade makes it increasingly difficult to control secondary contamination and to prevent such contamination from reaching infective levels during prolonged storage and handling in manufactured products.

Consequently, in the highly industrialized areas, very little salmonellosis is traced back to fresh cuts of meat but quite a lot to various prepared and manufactured meat products.

The Swedish meat-borne typhi-murium epidemic of 1953 gives an excellent illustration of the importance of in-slaughter surface contamination. This epidemic which totalled more than 10,000 human cases all over Sweden had its source in insanitary handling of carcasses in a large killing plant from which meat for manufacture was distributed to local establishments throughout the country. The epidemic strain was introduced into the killing plant apparently by some animal excreter, and established a high level contamination of the plant and plant equipment for a period of about four weeks. Altogether 3,974 carcasses of pigs, cattle and calves, killed during that period, were collected from cold storage plants around Sweden and submitted to bacteriological examination. Fifteen per cent of the total number of carcasses revealed surface contamination with S. typhi-murium with a maximum of 47.8 per cent for a specific date of killing. In 11 and 9 per cent respectively, the bacilli were shown to have invaded sub-surface muscular tissue and lymph nodes.

V ANIMAL VERSUS HUMAN EXCRETERS

The relative importance of animal versus human intestinal excreters as the source of food-contamination is difficult to evaluate correctly.

It is true that excreters commonly are detected among the staff in foodhandling establishments from which infected food products are being distributed, but the human excreters may just as well be victims and not the primary cause, having picked up the infection from the contaminated environment. Experience frequently shows this to be the case. The incidence of excreters in a non-exposed animal population has been found ten to twenty times higher than the incidence of human excreters, and in the case of meat and other foods of animal origin, it is thought that it can safely be concluded that contacts with animal faecal material, in general, are much more intensive than are contacts with human fecal materials.

VI EGG-BORNE SALMONELLOSIS: PREVENTIVE MEASURES

1. Restricted use of eggs other than hens' eggs

It has long since been realized that salmonella infection, especially S.typhi-murium, is of rather common occurrence in flocks of ducks, geese, pigeons and turkeys, and numerous incidents of human salmonellosis have been traced to raw dishes of eggs of these birds. In several countries, statutory regulations require eggs that are not hen's eggs to be marked by special stamps and prohibit their use for non-heated prepared foods.

2. How to reduce the incidence of salmonellosis in chickens

Of a more recent date is the observation that hen's eggs also not infrequently carry salmonellas other than S.pullorum-gallinarum. Under conditions such as they are in Denmark, flocks of ducks, geese and turkeys seem to act as the natural permanent reservoir of avian salmonellosis, while salmonellosis in poultry flocks occurs in a sporadic and transient way. It appears as if poultry is not an optimal host for the salmonella types in question. Poultry infections are due mainly to contacts with the aquatic birds or turkeys, and show no great tendency to persist in poultry flocks alone. Poultry, therefore, should be kept separated from other birds, and hatcheries should not be permitted to deal with hen's eggs together with other eggs. Moreover, regulations have been introduced requesting commercial hatcheries to accept eggs from ducks, geese and turkeys only, when the flocks from which the eggs were delivered have passed a blood test for S.typhi-murium and S.enteritidis within a month from the beginning of the hatching season.

3. Egg-storage

In infected flocks of poultry the morbidity rate usually is low while symptomless intestinal excreters are common. Following an outbreak of egg-borne salmonellosis in a hospital, we examined the flock of poultry in the hospital farm. Faecal swabs from 118 apparently healthy hens yielded S.typhi-murium in 28 per cent. In the store-room of the hospital we found 1,500 eggs laid by the infected flock. Only six showed growth of typhi-murium inside the egg. This means that even

in heavily infected flocks only occasionally does shell contamination penetrate into the egg. The limiting factors are temperature and humidity during storage. Experimentally, it was found that S.typhimurium does not invade through the intact egg shell at storage temperatures below 10-15°C or relative humidity below 90-95 per cent. At a level of 95 per cent relative humidity invasion takes place after nine days at 30°C, after eighteen days at 15°C, while no invasion was seen after two months at 4°C. At 17°C no invasion took place except when the level of relative humidity was kept as high as 90 per cent, or above. Overial infection and hence germinative infection of eggs with salmonella is in our experience very rare. Bacteriological examination of ovarian follicles from 2,600 hens plus nineteen batches of such follicles from an unknown but very large number of hens failed to reveal a single strain of salmonella.

4. Pasteurization of liquid egg

Although the all-over incidence of salmonella infected hen's eggs is still very low it is sufficiently high to cause contamination of a high percentage of large batches of liquid egg for drying, freezing or for the production of mayonnaise and other raw egg products. Both contaminated shells in breaking plants and eggs in which the infection has penetrated into the contents play a part in such contamination.

Homogenized liquid whole-egg and liquid egg-yolk can be pasteurized in plate-pasteurizers with three minutes holding time at temperatures between 64-66°C. For liquid egg-white the highest temperature which can be applied is 51-52°C; holding time three minutes. The last mentioned heat treatment is insufficient to destroy large numbers of salmonella but quite effective under ordinary conditions with a low initial number. A high degree of safety is reached by a combined chemical and thermal process, by which ammonia is added to the fermented egg-white until pH 10.5. After standing for twenty-four hours at temperatures not below 15°C, the alkaline mixture is pasteurized at 51-52°C. At the following process of tray - or spray - drying the ammonia will evaporate. The combined process of course is not applicable without subsequent drying. For frozen egg-whites only thermal treatment can be applied.

5. Acetic acid treatment of liquid yolk

In case pasteurized liquid yolk is not available for the manufacture of mayonnaise, raw liquid yolk may be rendered safe by adding acetic acid to the batch of egg yolk until pH has reached 4.5. Then the acid yolk-mixture is left at room temperature for four days before use.