CANADA

WP 11/84

(Canada.

Agriculture
Canada)

WORKING PAPER

Marketing and Economics Branch

Direction générale de la commercialisation
et de l'économie

[redacted]

ECONOMIC STUDY OF SALMONELLA POISONING AND CONTROL MEASURES IN CANADA

(Working Paper 11/84)

Leo Curtin

Food Markets Analysis Division
Marketing and Economics Branch
Agriculture Canada

August 1984

Comments on this study may be sent to the author, Agriculture Canada, Room 697, Sir John Carling Building, Ottawa, Ontario K1A 0C5 (613) 995-5880.

FOREWORD

This Economic Assessment of Salmonellosis and Control Measures in Canada has been prepared at the request of the Salmonella Coordinating Unit, to support recommendations to Agriculture Canada concerning control of *Salmonella*.

The Salmonella Coordinating Unit (SCU) was created in February 1980 to study the problem of *Salmonella* contamination in the poultry and meat industries with special emphasis on poultry. Its mandate was to develop specific action plans to reduce the incidence of *Salmonella* contamination of poultry and other meats as part of an Agriculture Product Quality Control Program.

ACKNOWLEDGEMENTS

To assist and guide this economic assessment, a Steering Committee was established consisting of the following members: A.H. Bentley, Salmonella Coordinating Unit, Agriculture Canada, chairman; Dr. W.S. Bulmer, Animal Health Division, Agriculture Canada; Dr. E.C.D. Todd, Microbial Hazards Bureau, Health Protection Branch, Health and Welfare Canada; E.S. Dunnett, Marketing and Economics Branch, Agriculture Canada; and L.C. Curtin, Marketing and Economics Branch, Agriculture Canada.

Further, I would like to acknowledge helpful comments on earlier drafts from H. Migie and R. Krystynak, Marketing and Economics Branch and from L. McCuaig and D. Brown, Salmonella Coordinating Unit, Agriculture Canada.

Full responsibility for the contents of this report remains with the author.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The purpose of this study is to describe and measure health problems that can be created by Salmonella species and to evaluate different measures to control Salmonella problems. Because of the lack of data concerning both the economic cost of human and animal salmonellosis, and the cost and effectiveness of the control measures, it is very difficult to give firm estimates of costs and benefits of these measures at this time. What we have done is attempt to set out a framework for looking at these costs and benefits.

In the first part of the study, we have analyzed the economic losses from human salmonellosis. Because of the high number of unreported cases, which can only be roughly projected, this total economic cost of $84 million per year is an approximation. Of this, $21 million is believed to be caused, directly or indirectly, by poultry products.

We have also estimated the cost of salmonellosis to the poultry industry, $2.8 million. Costs are mainly the result of higher chick mortality and a less efficient feed/conversion ratio. Most of this section is based on expert opinion.

The second part of the study tackles the question: "How to control Salmonella". Here we have limited ourselves to the control of salmonellae in the poultry industry, and to additional education to households and food service sector workers. We have divided the poultry sector into its components, from hatchery to processor and have evaluated control measures in each link of the chain. The effectiveness of the control measures is based, mainly on expert opinion and on a single detailed German study(13).

We analyzed the problems in producing salmonellae-free hatching eggs through the use of more hygienic conditions in the hatcheries.

At the producers' level, we estimated the cost of implementing more hygienic methods, and analyzed the Nurmi culture method which increases host resistance to Salmonella infection.

Several measures are studied at the processor level: clean and disinfected transportation crates, more hygienic conditions in the processing plant, the use of chlorine dioxide in the chilling water and the use of gamma irradiation of poultry carcasses.

The feed and renderer's industry is also studied and, finally, we have estimated the cost of educating the general public and the food-service employees concerning improved handling of food.

For each of the above control methods we have analyzed the cost and effectiveness. Based on these results and the cost of salmonellosis on humans and on the productivity of poultry, we compare the costs of the different measures and the expected benefits.

Our cost/benefit comparison is based on 1 year only. As more reliable numbers are obtained through experiments, the dynamics of the *Salmonella*-control programs may be evaluated.

Finally, because of a lack of data concerning the prevalence of salmonellae in other classes of the livestock sector, we have not included this sector in our analysis.

RISK ASSESSMENT

I SALMONELLA : THE PROBLEM

1. Symptoms/Hosts/Sensitive Populations/Serotypes

Salmonella food poisoning is caused by ingestion of a sufficient number of living *Salmonella* cells. The symptoms of salmonellosis in humans are: abdominal pain, diarrhea, chills, frequent vomiting and fever. The incubation period before symptoms occur generally ranges from 18 to 48 hours after ingesting food contaminated with salmonellae. The acute state of the illness may last one to two days and recovery is generally complete in seven days.

Humans may excrete salmonellae for a considerable period of time after infection. Most persons cease excreting salmonellae 3 to 4 weeks following infection but some may continue to shed for weeks, months or even years(17). Persons thus become carriers of salmonellae without showing any clinical signs. Without frequent lab examinations of stool specimens detection is almost impossible and asymptomatic carriers can be significant in causing future outbreaks of salmonellosis.

All persons are not equally susceptible to *Salmonella* infection. Whereas salmonellosis may cause some mild discomfort, or acute illness in healthy adults, it can often be very dangerous to infants and older people. Although death caused by salmonellosis is rare among humans, the illness may be a contributing factor in some cases.

The question of the infective dosage of *Salmonella* organisms has been extensively studied but it is difficult and indeed potentially misleading to give the number of *Salmonella* cells per gram that, when ingested, would cause salmonellosis. The establishment of a patent infection depends on dosage, serotype and strain, and susceptibility of the host. However, numbers as low as a few cells are known to have been responsible for illness.

There are approximately 2000 *Salmonella* serotypes known today, but only a relatively small number is found frequently. These serotypes can multiply between temperatures of 5°C to 60°C and very rapidly from 20°C to 45°C. At optimal temperatures their number can double every 20 minutes.

Most serotypes are found in either humans or in animals. Some, however, are primarily adapted to specific hosts and rarely cause disease in other animal species.
Host-adapted serotypes may cause severe illness including invasion of the blood stream, high morbidity and mortality

and may produce a permanent carrier state in the host. Examples are: Salmonella typhi and Salmonella paratyphi A, B and C in humans; Salmonella pullorum and Salmonella gallinarum in poultry; Salmonella dublin in cattle; Salmonella cholera-suis in swine; Salmonella abortus-ovis in sheep; and Salmonella abortus-equi in horses. Non-adapted salmonellae can cause less severe illness in both animals and humans(17).

In animals, salmonellosis can manifest itself in 3 types of syndromes: a peracute septicaemia, an acute enteritis or a chronic enteritis(2). In cattle, the peracute form occurs in newborn calves. Calves from one week of age and up to adult animals are most commonly affected by the acute enteric form. Chronic diarrhea, failure to grow and put on weight, and general debility may also be the extent of the clinical disease in some calves.

In pigs, the disease varies widely and, although the 3 forms of the disease occur in this species, there is often a tendency for one form to be more common in a particular outbreak. The main feature of the disease is enteritis. In some situations, pigs dying of septicaemia more commonly yield Salmonella cholera-suis, while those with acute enteritis are usually infected with Salmonella typhimurium.

In poultry, adult birds rarely show any clinical symptoms but often are carriers. Williams(35) notes as symptoms of salmonellosis in chicks: marked anorexia and increased water consumption; profuse and watery diarrhea with pasting of the vent.

2. Human Clinical Cases and their History

Since the early seventies, the incidence of human Salmonella infections appears to be increasing. Only part of this increase can be attributed to a greater awareness of salmonellosis by the public, physicians and public health groups. Data from the National Enteric Reference Centre, Department of National Health and Welfare, which reports the number of isolations of human salmonellosis recorded in Canada, clearly show this trend(24).

TABLE 1.1 REPORTED ISOLATIONS OF HUMAN SALMONELLOSIS IN CANADA

YEAR	TOTAL NUMBER
1970	4281
1971	5317
1972	4769
1973	5424
1974	5270
1975	4497
1976	4301
1977	5471
1978	8474
1979	8704
1980	8749
1981	9475
1982	9280

Source: Enteric Reference Centre, National Health and Welfare, Ottawa

Although 8500 cases of human salmonellosis do not appear significant, experts believe that these 8500 cases are only between 1 and 3 percent of the real incidence. Taking the unreported cases into account, the real incidence could be well over 500,000 cases per year. Furthermore, should the upward trend continue, the economic losses could become staggering.

It is difficult to compare the prevalence of human salmonellosis across countries because of differences in reporting systems and the levels of public awareness. Nevertheless, comparisons have been made by Pivnick and Nurmi(22). They calculated reported cases in 1979 per 100,000 population from various countries. There were 14 cases/100,000 people in the U.S., 10 in Denmark, 44 in Finland and 43 in Sweden. Accepting 8000 cases as an average reported number of human salmonellosis in Canada, the reported incidence would be 34 per 100,000 Canadians.

The Health/Agriculture/Industry Committee on Salmonella in its report on Scandinavian Salmonella control programs has also provided some statistics concerning the incidence of human salmonellosis(10). Denmark, with a population of 5,000,000 reports between 600 and 700 confirmed cases per year, or 12 to 14 cases per 100,000 inhabitants. One third of the cases are allegedly acquired by persons travelling abroad. Sweden reports 1,500 to 2,000 cases per year for a population of 8,000,000 people, or a rate of 19 to 25 cases per 100,000. Supposedly 2/3 of these incidents are due to persons travelling outside the country. In 1976, Germany, with 60 million inhabitants, reported 40,560 cases of human salmonellosis, 68 cases per 100,000 persons.

Unfortunately, no data are available to show whether the incidence of human salmonellosis is increasing or decreasing in these countries.

3. Clinical Cases in Animals

The data about salmonellosis in animals are even more difficult to obtain than information about human salmonellosis.

There appear to be no historical data that would indicate whether animal clinical salmonellosis is increasing or decreasing. We are limited, therefore, to briefly describing the situation in some countries.

In Denmark, Salmonella species were isolated from only 2-3% of hogs. Danish Veterinary Services believe that clinical Salmonellosis is non-existent in Danish pigs. There is no inspection for Salmonella in pork at retail(10).

In Canada, studies have shown a 25-35% incidence of Salmonella in pigs and clinical salmonellosis is present within the Canadian hog industry. Poultry is mainly a carrier of salmonellae and seldom suffer ill effects. Few data are available regarding salmonellosis in cattle. An article about Salmonella muenster isolations in Ontario shows the increasing numbers of isolations of that serotype against the total number of isolations(1).

TABLE 1.2 SALMONELLA ISOLATION FROM NON-HUMAN SOURCES IN ONTARIO

	SALMONELLA ISOLATION	SALMONELLA MUENSTER
1978	633	19
1979	543	38
1980	690	69
1981	973	253
1982	1451	595

Although these data are not representative for all of Canada, they do indicate that a problem could exist in livestock. However, the Salmonella isolations do not necessarily mean clinical cases in animals.

A 1983 German study by Dr. Krug and Dr. Rehm(13), which was done over a period of four years has made some assumptions concerning the incidence of clinical salmonellosis in livestock.

TABLE 1.3 CLINICAL SALMONELLOSIS IN LIVESTOCK IN WEST GERMANY

	CATTLE	CALVES	HOGS
Number	12,822,000	2,228,000	22,374,000
Clinical salmonellosis	576,990	316,376	2,500,000
Percent	4.5	14.2	11.2

Source: KRUG, 1983 West-German Statistics, Expert Opinion.

II SOURCES OF INFECTION

It is often difficult to determine the source of *Salmonella* infection. There are several reasons for this. For one, there is a time lag between the infection and the moment *Salmonella* is isolated and identified as the responsible factor. The source of infection, in human salmonellosis often food, may already have disappeared. For a person to become infected with salmonellae, the following sequence of events must occur(3):

1) *Salmonella* must be present either in citizens of a community, in food-source animals, or in the environment;

2) The agent must contaminate a food during the growing period or during harvesting, processing, storage, or preparation;

3) Enough time at a temperature suitable for bacterial growth;

4) Sufficient quantities of the contaminated food that contain levels of salmonellae exceeding a person's resistance-susceptibility threshold must be ingested.

A United States study investigated factors that contributed to outbreaks of salmonellosis in the U.S., Canada and in England/Wales. The following table shows these results in percentages(4). These factors are not mutually exclusive.

TABLE 2.1 FACTORS THAT CONTRIBUTED TO OUTBREAKS OF HUMAN SALMONELLOSIS

FACTORS	U.S. (1961-75)	CANADA (1973-75) %	ENGLAND/WALES (1969-76)
Factors affecting contamination			
- contaminated raw ingredients	32	14	41
- cross contamination	21	23	26
- inadequate cleaning of instruments	15	14	19
- infected persons	13	18	4
- unsafe source	1		30
Factors affecting survival			
- inadequate cooking, heat processing	21	10	41
- inadequate reheating	13		22
Factors affecting growth			
- improper cooling	47	41	63
- improper hot holding	14	5	15
- laps of day or more between preparation and serving	21	18	52
- use of leftovers	4		
- faulty fermentations	1		
- inadequate thawing			4

Source: Bryan, 1981

When numbers of pathogens insufficient to cause illness are ingested, an infected individual may become a carrier and may cross-contaminate other foods.

The Department of National Health and Welfare publishes an annual summary of food-borne and water-borne diseases in Canada. In the latest publication for 1978(11), they have identified the places where food was mishandled and resulted in human salmonellosis. Food-service establishments accounted for 64.3% of the cases, homes for 4.6%, food processors for 12.2%, retail food establishments for 2.0%, other and unknown sources for 0.2 and 16.7%, respectively. Although a place may have mishandled the food, this does not mean that it was the source of the initial contamination. It may be that their mishandling the food allowed the salmonellae to multiply to sufficiently high numbers to cause infection. Statistics show, year after year, that the great majority of human Salmonella infections are caused by food being mishandled in food-service establishments. In 1978, of the 1396 identified cases of salmonellosis caused by improper handling of food in food-service establishments, 408 occured in restaurants and hotels, 750 in catered groups, 128 in institutions including schools, 66 in clubs and churches and 44 in camps.

A study conducted in Trier, West-Germany(13) has tried to establish the sources of Salmonella contamination/infection and, based mostly on expert opinion, the authors accepted that:

- 77% of salmonellae in animals is derived from feeds;

- 72% of salmonellae in food is derived from animals;

- 2% of salmonellae in food is derived from water; and

- 81% of salmonellae in humans in derived from food.

In Canada, poultry is often identified as one of the main sources of human salmonellosis. One of the reasons for this is that serotypes most frequently isolated from chicken carcasses are also most frequently found in humans. Following is a list of the 10 most frequently isolated serotypes from broiler carcasses and from humans in Canada in 1978.

TABLE 2.2 SALMONELLA ISOLATIONS FROM BROILER CARCASSES AND HUMANS IN CANADA

	FROM BROILER CARCASSES (1978)	FROM HUMANS (1978)
1.	S. typhimurium	S. typhimurium
2.	S. infantis	S. heidelberg
3.	S. saint Paul	S. infantis
4.	S. heidelberg	S. enteritidis
5.	S. schwarzengrund	S. typhi
6.	S. thompson	S. saint Paul
7.	S. montevideo	S. haardt
8.	S. nienstedten	S. agona
9.	S. haardt	S. montevideo
10.	S. bredeney	S. schwarzengrund

Source: SCU

From the above list of most frequently isolated serotypes in poultry and humans, it appears that a possible cause/effect association exists. Year after year, 85-90% of human salmonellosis in Canada is caused by the same serotypes that we find in poultry while these same serotypes account for only 20-40% of all the isolates from other non-human sources. Much research has been done to explain the connection and it would be worthwhile to look at the results in more detail because the incidence of Salmonella contamination at different links in the poultry industry chain may give a hint as to where to concentrate "clean-up" efforts. In the Canadian poultry industry the following levels of Salmonella contamination were found(24):

TABLE 2.3 PREVALENCE OF SALMONELLAE IN THE CANADIAN POULTRY INDUSTRY

Breeder - day-old chicks	20-25% of lots
Hatchery supply flocks	50%
Hatcheries	5% of lots
Broiler farms	55% +
Turkey carcasses at processors' level	60% +
Chicken carcasses at processors' level	50-60%
Poultry crates	60%
Mixed feeds	6%
Rendered product	20-30%

Source: SCU

As is immediately obvious, Salmonella contamination of chicken and turkey carcasses at processor's level is very high. In most cases the numbers of Salmonella present are low. However, improper handling can allow for very rapid growth of the bacteria. Furthermore, cross-contamination can occur through direct contact with other foods, hands, utensils and cutting boards. Since salmonellae are generally killed during cooking, most prepared chicken and turkey products are Salmonella-free. However, contamination of utensils and equipment prior to cooking can re-contaminate such food. This danger is greater for turkey because often it is not consumed in one day and the leftovers are not always properly stored, providing ideal conditions for growth of salmonellae. The preparation of food for consumption the next day increases the chances of Salmonella poisoning.

A contributing factor to the high number of human salmonellosis attributed to poultry may be the increasing per capita consumption of poultry in Canada. This rose from 14.73 kg. in 1963 to 22.48 kg. in 1982, a 53 percent increase(9).

The contamination of other foods is not as well documented. In pork chops the prevalence of salmonellae has been found to be 2 percent, pork sausages 10 percent(24). In the hog industry, a contamination of 25 to 30 percent of the hogs has been observed and tests of dehairers at pork slaughter sites have indicated 30 percent positive results. An important contributing factor in contamination appears to be stress situations to which animals are subjected. Surveys have shown that, although the percentage of swine shedding salmonellae may be low in the farm environment, it is dramatically increased during transportation and during holding before slaughter(19).

In animals, feeds are often identified as the main source of infection. The German study indicated that 77 percent of cases of *Salmonella* infection in animals is derived from feed. Many European studies support this premise, although most do not attempt to quantify the relationship(10, 18, 34). Transmission from animal to animal is very common, especially where they are reared in groups, as is the case for poultry and hogs.

Recently, the importance of the transportation crates has been recognized as a vehicle of contamination of poultry. Trucks that transport animals to slaughter and processing plants have also been found to be heavily contaminated(23).

Wild birds and animals are often carriers of salmonellae and this makes it more difficult to prevent infection in domestic animals.

III WAYS OF CONTROLLING SALMONELLA (HISTORICAL)

To control *Salmonella* effectively, it is not sufficient to implement a single control measure, but to involve as many sectors of the foodchain as possible. A well coordinated effort is needed involving industry clean-up and education of producers, processors and consumers.

Evidence indicates that Salmonella infection is most often caused by ingestion of food, although other sources of infection also play an important role.

Cooking foods at an interior temperature of 70°C for a few seconds will kill all salmonellae present. However, it is often the handling of cooked food that results in recontamination and rapid multiplication of Salmonella. Should the food be recontaminated (by a small number of bacteria) after cooking and stored under inadequate conditions, then the bacteria could multiply at a very fast rate (maximum: double every 20 minutes). It is easy to see that a recontaminated turkey, left overnight on the kitchen table, can lead to Salmonella food poisoning the next day. Should that same turkey be properly stored, then the bacteria may not grow, and ingestion of the small number of salmonellae may not lead to any illness.

Thus, unless the soures of Salmonella in raw foods are reduced, salmonellosis will remain a significant problem.

Some countries have concentrated their efforts on the clean-up of the industries, thus preventing the salmonellae from entering the food chain. We will look at the programs in some Scandinavian countries, at the efforts in Canada and at some experiments to reduce _Salmonella_ contamination within the industries.

1. _Control Efforts in Other Countries_

Some countries, such as Sweden, Denmark and Finland have a national approach towards the reduction of _Salmonella_. We will briefly describe their programs(10).

a) _Sweden_

The Swedish Salmonella Eradication Program has been developed following several procedures:

1. Control over the importation of live poultry - quarantine plus monitoring for 5 months.

2. Control over production and importation of feedstuffs:

    - all imported rendered product must be free of _Salmonella_;

    - all rendered products produced must be certified free of _Salmonella_.

3. Control over all breeders, hatchery supply flocks and broiler production and elimination of all positive birds:

   - any flock in which a <u>Salmonella</u> organism is found, was destroyed and buried or burned, but this has been relaxed recently.

4. All livestock suspected of having a Salmonella infection are investigated and if necessary quarantined until free of infection.

5. Human food handlers are subjected to a medical examination.

b) <u>Denmark</u>

1. Control over the importation of breeding stock:

   - quarantine plus monitoring for 4-5 months.

2. Control over importation of feedstuffs:

   - testing of all imported meat, bone and fish meals, and the re-sterilization of all lots before being mixed in commercial feeds.

3. Separation of water fowl (ducks and geese) from turkeys and chickens:

   - separate hatcheries for each poultry type;

   - no waterfowl on breeding farms;

   - no waterfowl on hatching egg producing farms.

4. All suspected Salmonella problems in farm animals, cage birds, or laboratory animals, as well as those found at food inspection, must be reported.

5. Special control measures for breeding centres.

c) Finland

Finland's control system is similar to Sweden's but it does not require that hatchery supply flocks and broiler flocks be automatically destroyed when found positive for Salmonella. They prefer to raise the birds to commercial size, slaughter them and heat process the meat. It is estimated that half of the broilers in the country are treated with the Nurmi culture. A survey of market birds showed that one processor, who claims that his growers use the Nurmi culture all the time, was the only one free of Salmonella.

2. Control Efforts in Canada

In Canada, the *Salmonella* problem has been recognized and has gained public attention since the early seventies. Other than for *Salmonella pullorum* and *Salmonella gallinarum*, there is no national program. It must be mentioned, however, that in the framework of food safety, pasteurization of egg products and milk has been enforced.

In 1974, the Interdepartmental Salmonella Committee (ISC) was created, composed of members from Agriculture Canada, Environment Canada and Health and Welfare Canada. The aims of this Committee were:

a) to formulate recommendations on methods and regulations that would ensure a reduction of salmonellosis in the human population and the foodchain;

b) to recommend educational programs to increase public concerns;

c) to recommend ways of increasing departmental cooperation.

In November 1981, ISC under chairmanship of Dr. J.Y. D'Aoust revised its terms of reference to read as follows:

a) recommend to pertinent government agencies actions for the abatement of *Salmonella* in humans, animals and other known sources;

b) review the adequacy of municipal, provincial and federal programs for the control of *Salmonella* and make recommendations for improvement where indicated;

c) review the effectiveness of educational programs designed to increase the awareness of food manufacturers and consumers to the health and economical implications of *Salmonella* contamination and make recommendations where indicated;

d) foster interdepartmental cooperation;

e) provide a forum for federal departments to exchange information and express concerns on the incidence of *Salmonella* in the environment.

In 1979, the Poultry Industry - Agriculture Canada Committee on *Salmonella* was set up to exchange information, identify research areas and make recommendations for the abatement of *Salmonella* contamination.

In February 1980, the Salmonella Coordinating Unit was established$^{(24)}$.

The food service sector has recognized the problem that Salmonella can cause their industry, and has taken steps to improve foodhandling. The Canadian Restaurant and Foodservices Association, which represents almost half of the restaurants in Canada, has formulated the "Sanitation Code", which focuses attention on the need for training within the food-service industry. In 1973, it produced the National Sanitation Training Program which offers four individual courses(6).

From the above it would appear that, although we do not yet have a national Salmonella eradication or reduction program, the problem is recognized and investigated.

3. Some Results from Recent Experiments

A major problem in controlling Salmonella infection in animals is that many are carriers but show no clinical signs of the infection. Identification is therefore often very difficult. If producers could bring a Salmonella-free product on the market, then the problem of human salmonellosis would be greatly reduced. We do not say eliminated because of external incontrollable sources of contamination, such as wild birds and rodents. Research indicates that it is possible to deliver a "clean" product to the market. We will give some examples, mainly from the poultry sector, where the prevalence of salmonellae was reduced.

First of all, *Salmonella pullorum* and *Salmonella gallinarum* which caused severe problems 30 to 40 years ago, have virtually disappeared from commercial poultry flocks in Canada. Here it must be mentioned, however, that detection of these two strains could be done by a simple blood test. *Salmonella gallinarum* and *Salmonella pullorum* are reportable diseases under the Animal Disease and Protection Act. When either of these diseases are reported to the Animal Health Division (Agriculture Canada), the premises on which they are found are immediately quarantined and action taken to either destroy the bird population or to eliminate the disease(24).

An Australian study(12) reported that a reduction in infection rates was achieved through segregation of eggs from known clean and infected flocks, strict attention to hygiene on farms, placement of clean chicks onto cleaned farms and close supervision of pelleting and handling of finished feeds. The results were very encouraging. The overall prevalence of salmonellae in 96 broiler houses was reduced from 95.8% to 12.5% after 1 year and to 2.1% after 2 1/2 years whereas the incidence of *Salmonella* *typhimurium* was reduced from 87.7% to 8.3% to 0% over the same period of time.

During the same research project the prevalence of salmonellae in 64 infected breeding houses was reduced from 89% to 18.8% after 1 year and to 1.6% after 2 1/2 years; *Salmonella typhimurium* infection rates were reduced from 65.6% to 4.7% to 0%.

A recent but very promising method of controlling salmonellosis is the Nurmi culture(25). It involves oral administration of the gastro-intestinal flora from *Salmonella*-free adult birds into newly hatched chicks and poults. Although it does not eradicate *Salmonella* species, it greatly reduces the level of infection by increasing competition for intra-intestinal nutrients required by *Salmonella*.

Immediately after introduction of gastro-intestinal flora from adult birds, chicks become resistant to between 1,000 and 1,000,000 infectious doses of *Salmonella* organisms(25).

A survey by Dr. Nurmi in Finland on the incidence of broiler carcasses yielded the following results(10):

processing plant	number of samples	% positive
1	69	7.2
2	160	10.0
3	75	9.3
4	236	14.0
5	207	0

Source: Survey by Dr. Nurmi

Processor #5 claims that all his growers use the Nurmi culture for all flocks, and processor #4 uses the Nurmi culture least often. Dr. Nurmi estimated that half the broiler farms in Finland use the Nurmi culture.

A Canadian Study by Rigby et al.(23) showed that, even when broilers are raised *Salmonella*-free, contaminated crates can still lead to infected birds arriving at the processing plant. The same research indicated that the transportation crates can be effectively washed and disinfected.

The processor has a responsibility to limit cross contamination. Simard and Auclair(26) showed that it is possible to drastically reduce the degree of contamination in processing plants. Through identification of the critical points in the processing plant, use of effective disinfectants, use of proper cleaning equipment and education and training of plant management and staff they reduced the number of *Salmonella* positive plant surface samples from 76.9 percent to 2 percent over a period of one year.

An interesting study was done in the Netherlands by Oosterom(20) concerning the possibility of raising Salmonella-free hogs in a real-world environment. Previous research had shown that in an experimental environment this was possible. However, attempts to fatten pigs Salmonella-free under actual industrial circumstances proved less successful. An existing hog growing installation which was known to be contaminated with mainly Salmonella typhimurium, was chosen as a research site. There were three hog barns and one was controlled to eliminate Salmonella contamination. The piglets which were bought, came from a piggery where Salmonella london and Salmonella panama were prevalent. The experimental barn and the transportation trucks were cleaned and disinfected. The results showed that it was not possible to raise Salmonella-free hogs; 68 percent of the tests were Salmonella positive, whereas in the control barns a contamination of 81 percent was recorded. The researchers were, however, successful in barring Salmonella typhimurium from the experimental barn, thus showing that it is possible to put up contamination barriers against specific species of salmonellae. An interesting finding was that, although it was not possible to grow the hogs free of all salmonellae, the pigs which were maintained free of Salmonella typhimurium in the experimental barn showed a feed-conversion ratio of 3.00 whereas it was 3.35 for the other ones. Laboratory investigation showed that in the control barns transmissible gastroenteritis and Aujeszky-virus were present. It was thus shown that the hygienic conditions of the experimental barn were capable of preventing other diseases, contributing to a more efficient conversion of feed to meat.

The second stage of the experiment concerned the slaughtering conditions. One half of the hogs were slaughtered as usual. The other half were scalded individually and the guts were carefully removed. Examination of the carcasses showed that 46 percent of the first group were contaminated with salmonellae, but only 7 percent in the group, in which care was taken to avoid contamination from intestinal contents.

The above examples show that it appears possible to reduce Salmonella infection in animals. It is also important to maintain a Salmonella reducing effort at all times and at all levels of the growing chain.

IV ESTIMATES OF COSTS OF SALMONELLOSIS

Several studies are available that have attempted to estimate the cost of human salmonellosis. Estimation of the cost of a particular outbreak is not overly complicated, but the total economic costs of human and animal salmonellosis is much more difficult to calculate. The lack of reliable data is the main problem, because it must be replaced by expert opinion which by nature is subjective. We will briefly discuss some studies that have estimated the costs of salmonellosis in general or of specific outbreaks.

1. German Study

A comprehensive study was undertaken on behalf of the Government of the Federal Republic of Germany at the University of Trier over a period of four years(13). The authors estimated the cost of salmonellosis to humans and animals.

a) Humans

For humans in 1977, 28,772 cases of salmonellosis were reported and it was estimated that the real incidence was 13.4 times higher i.e. 385,545 cases. The human population of West Germany is approximately 60 million. We have converted the costs in DM into Canadian dollars using the 1977 conversion ratio of .46 C$ for $1 DM, and adjusted the 1977 figures to 1982 for the inflation in Germany(9).

TABLE 4.1 COST OF HUMAN SALMONELLOSIS IN GERMANY

COST TYPES	REPORTED CASES 28,772 C $	NON-REPORTED CASES 356,773 C $	TOTAL 385,545 C $	%
Medical costs	3,994,029	3,571,266	7,565,295	12
Welfare costs	1,795,482	12,054,747	13,850,229	23
Examination cost	3,588,824	-	3,588,824	6
Loss of leisure	7,550,965	18,631,724	26,182,689	42
Loss of consumption	2,954,079	6,891,205	9,845,284	16
Other costs	656,462	-	656,462	1
Total	20,539,841	41,148,942	61,688,783	
%	33.3	66.7	100	
average per case	$714	$115	$160	

Source: KRUG and REHM, 1983

Welfare costs are caused by the loss of productive output and are calculated using the net income of the ill person as an approximation of this loss.

Examination costs are laboratory costs incurred when stool samples are sent to labs.

Loss of consumption is due to the fact that ill individuals will spend less on food, transportation, etc.

b) Animals

Expert opinion was used to determine the number of Salmonella infected animals. It was estimated that out of 12.8 million heads of cattle, 3.2 million were infected with Salmonella and that 560,000 head would be clinically ill. Similarly, it was estimated that 316,376 calves would be clinically ill out of a total calf population of 2.2 million. The costs would be as follows:

TABLE 4.2 COST OF SALMONELLOSIS IN CATTLE IN GERMANY

COSTS	C $ ('000)	PERCENT
Examination cost	9,482	15
Quarantine/isolation costs	22,236	34
Loss of milk	1,299	2
Isolation slaughter	59	-
Bacteriological examination	95	-
Loss of meat	25,363	39
Diagnostic Examination	23	-
Weight loss	5,825	9
Environmental cost	759	1
Total	65,141	100.0

Source: KRUG and REHM, 1983

Examination costs represent the costs of analysis of stool specimens for Salmonella.

Quarantine/Isolation costs are caused because it is necessary to build isolation facilities for infected animals. Loss of milk is caused because the milk from an infected herd is deemed unfit for consumption and is discarded.

Isolation slaughter is due to the fact that some animals are killed to allow for the bacteriological examination of meat.

Loss of meat results from the classification of animals in the slaughterhouse as unfit for consumption.

For cattle, weight loss was estimated as 10% for an average duration of salmonellosis of 28 days. For hogs, weight loss was estimated as 10% for a duration of 14 days.

In the poultry industry, they assumed the loss due to salmonellosis in the producing sector between 0.5 and 1.26 percent of the chick population. For the processing industry it is assumed that one third of all rejection is caused by Salmonella, i.e. 1/3 (0.5 - 1.0 percent). Total costs are calculated by multiplying the eliminated or rejected birds by their market price. Total loss would therefore lie between $4,356,145 and $10,280,319.

The total economic losses due to Salmonella in West-Germany can be summarized as follows:

TABLE 4.3 TOTAL COST OF SALMONELLOSIS IN GERMANY

	MILLIONS C $		PERCENTAGE	
Humans	61.7		45	
Animals	74.9		55	
- cattle		64.2		47
- hogs		3.4		2
- poultry		7.3		6
Total	136.6		100	

Source: KRUG and REHM, 1983

2. Scottish Study

This research by D.R. Cohen(5) at the University of Aberdeen studied the benefits and costs of a ban on the sale of non-pasteurised milk in Scotland. For our purpose we will take a look at the cost of a milk-borne salmonellosis outbreak in the Grampian region in 1981. There were 654 reported cases of which 448 were laboratory confirmed. Cohen distinguishes between tangible and intangible costs, and each one is further divided into direct and indirect costs. The following tables show the cost of the outbreak. We have converted British pounds into Canadian dollars using the conversion ratio of 2.1579 Canadian dollars for 1 pound and adjusted the figures for 1982 inflation in Great-Britain(9). For the intangible costs he provides a range of values, based on different assumptions.

TABLE 4.4 TANGIBLE COSTS OF A SALMONELLOSIS OUTBREAK IN SCOTLAND

1) Direct costs		
a. Medical	$77,035	
- hospitalization		$ 47,514
- general practitioners		$ 5,925
- field work nurses		$ 14,515
- senior medical/nursing staff		$ 4,686
- administrative and clerical		$ 3,186
- others		$ 1,209
b. Laboratory investigations	$ 5,012	
c. Phage typing	$ 3,491	
d. Veterinary	$ 2,132	
e. Environmental health surveillance	$14,234	
Total direct tangible costs		$101,904
2) Indirect costs		
f. Travel to visit hospital patients	$ 6,732	
g. Loss of productive output	$86,372	
Total indirect tangible costs		$ 93,104
Total tangible costs		$195,008

TABLE 4.5 INTANGIBLE COSTS OF A SALMONELLOSIS OUTBREAK IN SCOTLAND

	MINIMUM	MID	MAXIMUM
1) Direct costs			
Loss of housewives output	$ 18,006	$ 36,012	$ 72,024
2) Indirect costs			
Pain grief and suffering	78,373	156,747	235,120
value of lost life	225,387	3,642,194	7,029,000
Total intangible costs	321,766	3,834,953	7,336,144
total tangible cost	195,008	195,008	195,008
Total cost of outbreak	516,774	4,029,961	7,531,152
Cost per reported case	$ 790	$ 6,162	$ 11,515

Source: COHEN, 1982

In this outbreak, two deaths were associated with salmonellosis. The large range in cost associated with loss of life reflects the controversy how to measure the value of life. This study does not mention any economic losses in animals because of salmonellosis.

3. Other Studies

Levy and McIntyre(16) studied the cost of an outbreak of food-borne salmonellosis in a town in Minnesota in 1974. Approximately 125 people developed salmonellosis, 50 of them consulted physicians and 11 were hospitalized. The costs (expressed in 1982 dollars) are converted at a rate of 1.2 Canadian dollar for 1 American dollar.

- Medical and hospital expenses	$ 7,664
- Cost of investigation	$ 5,544
- Economic impact on restaurant owner	$12,000
- Lost salaries and productivity	$43,699
Total	$68,907

The average cost per case was calculated at $551 ($68,907 ÷ 125).

The cost of salmonellosis in Canada was estimated by Finn(7). The number of reported cases in 1974 was 5000 with 8 mortalities. This would include 2202 workers. He further assumed 10 unreported cases for each reported one. Following table gives a brief overview of the results.

TABLE 4.6 COST OF SALMONELLOSIS IN CANADA (in 1982 $)

1. Foregone wages	$ 8,378,874
2. Hospitalization costs	3,520,000
3. Cost of loss of life (present value)	380,913
4. Medical costs	1,760,000
5. Loss of animal productivity	1,056,000
6. Retail ban of 1 week on chicken (probability of 1 ban in 20 years)	405,041
Total costs	$15,500,828

Source: FINN, 1976

The average cost per case of human salmonellosis would be: $14,039,787 ÷ 55,000 = $255, and per reported case: $14,039,787 ÷ 5,000 = $2,808.

The study also attempted to calculate the impact of improved poultry industry conditions on chicken productivity. The productivity increase in the poultry sector, due to improved sanitation was assumed as an overall improved growth rate performance of broilers by one-quarter percent in terms of the weight of finished broilers and a one quarter percent reduction in chick mortality. These estimates were based on expert opinion.

The above studies clearly demonstrate the problems that surround estimating the cost of salmonellosis to humans and to animals. Every study uses different cost categories and different assumptions. Comparisons are therefore very dangerous.

4. Estimate of Costs of Salmonellosis in Canada

We have estimated the cost of salmonellosis in humans in Canada during 1978 (using 1982 dollars). That year there were 8474 reported cases and we assumed that this represented only 2 percent of the real incidence. Our methodology is similar to the German study, although not identical. The detailed calculations can be found in appendix A, and we limit ourselves here to give the results. Note that all costs are in 1982 Canadian dollars.

TABLE 4.7 ECONOMIC COSTS OF HUMAN SALMONELLOSIS IN CANADA

	HOSPITALIZED 1,625 cases	REPORTED NON-HOSPITALIZED 6,849 cases	NON-REPORTED 415,226 cases	TOTAL 423,700	%
Hospital and medical cost	$4,198,859	$ 869,823	$ 0	$ 5,068,682	6.1
Loss of productive output	456,450	806,964	27,470,533	28,733,947	34.3
Loss of leisure	674,251	1,215,925	45,573,432	47,463,608	56.7
Investigation cost	76,375	321,903	-	398,278	0.5
Loss of life	1,986,194	-	-	1,986,194	2.4
TOTAL	7,392,129	3,214,615	73,043,965	83,650,709	
average	$ 4,549	$ 469	$ 176	$ 197	

The weighted average cost for reported hospitalized and reported non-hospitalized cases of human salmonellosis is $1,252.

The range of total costs would be between $58.8 million and $158 million (APPENDIX A).

For poultry, we have estimated the cost of Salmonella contamination at $2,759,116 (Appendix B). These estimates are based on the increase in poultry output, caused by reduced chick mortality and improved feed conversion ratio, because of reduced prevalence of salmonellae.

Because of insufficient data, it has not been possible to calculate the cost of Salmonella infection in the livestock sector.

RISK MANAGEMENT

In part I we have established that a Salmonella problem exists and that the apparent economic losses caused by salmonellosis are substantial. We will now concentrate our efforts on investigating ways of reducing the prevalence of Salmonella in the food chain and of salmonellosis in humans and in animals. Lack of reliable data in all areas will cause us to focus most of our attention on the poultry sector. If we are putting less emphasis on the beef and pork sector, it is not because we believe that these sectors are Salmonella-free, but because we have insufficient data to make adequate inferences concerning the degree of salmonellae infection and contamination in these areas.

We will first analyze the structure of the poultry industry and the level of salmonellae infection/contamination in each segment. It is important to understand the linkages between the different segments in the poultry sector to determine the impact of a Salmonella control measure in one area on the industry further down the producing/processing chain.

V STRUCTURE OF THE POULTRY SECTOR

We will give a brief overview of the poultry sector starting at the beginning of the chain and working our way down the line to the point where poultry is consumed. It is important to notice that a measure taken to control salmonellae in one segment will have an impact farther down the feed-producer-processor-retailer-consumer chain. Equally important, failure to correct a situation favourable to the growth of salmonellae in one area will cause infection in subsequent areas.

1. Primary breeders

This sector provides animals for the hatchery supply flocks. Canada imports approximately 95% of its breeding stock as day-old chicks from the United States (A.H. Bentley, Livestock and Poultry Products Division, Agriculture Canada; Personal Communication). There are only three Canadian breeders: one each for egg-layers, broilers and turkeys. It is estimated that 15-25 percent of the breeder flocks, imported as day-old chicks are carrying salmonellae(24). The Canadian industry has no control over the Salmonella-status of the imported day-old chicks, Salmonella pullorum and Salmonella gallinarum excepted(24).

2. Hatchery Supply Flocks

Hatchery supply flocks, or multiplier flocks, multiply the stock developed from primary breeders. Samples of nest litter taken from hatchery supply flocks indicate that salmonellae are present in 50% of the flocks(24). Most provinces have a hatchery supply flock policy that allows monitoring and testing for poultry diseases.

3. Hatcheries

In 1982, there were 138 federally registered hatcheries in Canada. Annually, 15-25% of the hatching eggs are imported from the U.S.. Salmonellae are present in only 5% of the lots of commercially hatched chicks(24). It appears that, to a large degree, hatcheries act as a natural barrier between breeders and producers.

4. Producers

There are approximately 2,000 egg, 2,500 broiler and 500 turkey producers(15). Salmonellae are found on about 50% of the farms. It is believed that residual contamination plays an important role here. Often barns and equipment are not adequately cleaned and disinfected between crops of birds(24).

5. Processors

Recent studies have indicated that over 50% of poultry carcasses are contaminated with salmonellae(24). Live birds arriving at the processing plant became infected or contaminated at three locations: in the hatchery, on the farm or during transportation because of contaminated poultry crates or from association with other contaminated birds. In 1983, there were 90 processors in Canada. Hygienic conditions in the plant can limit further contamination and extreme care should be exercised to ensure that this is the case.

6. Feed manufacturers

It is estimated that six to eight percent of the poultry feed in Canada is contaminated with salmonellae(24). Furthermore, feed trucks are not always under the direct control of the feed manufacturer or are not routinely cleaned and disinfected, and cross-contamination remains a strong possibility. Since feed is constantly introduced to poultry on the grower station, it is imperative that the feed be Salmonella-free if the degree of Salmonella infection in broilers is to be controlled.

7. Renderers

Twenty to thirty percent of all rendered products have been found contaminated with salmonellae(24). This is generally due to recontamination of the finished product after heat processing.

VI CONTROL MEASURES

We will analyze the measures that can be taken in the different sectors of the poultry industry to control Salmonella. Since estimating the additional cost for each measure would be nearly impossible without conducting a comprehensive survey of the industry, we must often limit ourselves to describe and qualify these measures. However, where possible, a detailed cost calculation will be given. All costs are expressed in 1982 dollars. Since 95% of the primary breeders are imported as day-old chicks, and a slightly lower percentage for egg-type stocks and turkeys, we will concentrate our analysis on the subsequent sectors of the poultry industry.

1. Production of clean hatching eggs

Clean hatching eggs produced by the hatchery supply flocks can be ensured by maintaining hygienic conditions in the hatchery supply flocks and hatcheries (see APPENDIX C).

To make an audio-visual available that shows how to improve the hygienic conditions in this sector is estimated at $15,000 (see p. 53). These improvements would require additional labour of 10 hours per week per flock(7) for a total cost of
10 x 52 x 450 x $9.00 = $2,106,000.

One important measure would be the fumigation of eggs on the farm. There are approximately 450 hatchery supply flocks in Canada and only 10% is estimated to have a fumigator. The cost of a fumigator is estimated at $1800 by Finn(7) and the cost for adjusting the building at $500 (Bentley, Personal Communication). The additional costs would therefore be $150,402 per year. We have assumed a 12% interest rate and a life expectancy of 10 years for the fumigators and 20 years for the buildings.

2. Maintenance of a clean hatchery environment

In general, hygienic conditions at the hatchery level are satisfactory, but care must be taken to maintain this level. The hatchery is the ideal area where the *Salmonella* infection chain can be broken. Indeed, with a current contamination rate of 5% they already act as a significant barrier for the spreading of salmonellae. In addition to insisting in accepting fumigated eggs only, salmonellae spreading can be controlled if hatchery men maintain a very hygienic hatchery environment (APPENDIX C).

Audio-visual presentation is estimated to cost $15,000. We assume that it would cost $645,840 per year in terms of increased labour to improve hygiene conditions in the hatcheries (52 weeks x 10 hrs/week x 138 hatcheries x 9 $/hr).

3. Control measures in the grower barns

We will investigate the possibility of a cleaner environment in the growing stations and the introduction of the "Nurmi Culture." A more hygienic environment in the barns can be obtained by adhering to strict hygienic work methods (APPENDIX C). Educating this sector was estimated at $41,250.

There are approximately 3,000 registered producers in Canada, and it was estimated by Finn that the improved hygienic conditions could be achieved by increasing labour by 4 hours per week per flock(7). Additional costs, therefore, would be 3,000 x 4 x $9 x 52 = $5,616,000.

The Nurmi culture consists of oral administration of the gastro-intestinal flora from adult birds into newly hatched chicks and poults. It would greatly increase the resistance to salmonellae infection. Dr. Nurmi has estimated that to provide the culture on an industrial scale by a commercial firm would cost one Canadian cent per pound(10). For 1983, this would amount to:

- chicken:	511,785,000 kg x $0.03 =	$15,353,550
- turkey:	130,265,000 kg x $0.03 =	$ 3,907,950
	TOTAL	$19,260,500

We have assumed that it would now cost 3 Canadian cents <u>per kilogram</u> to provide the Nurmi culture.

It should be mentioned that a research project is underway, studying the Nurmi Culture in detail. However, seeing that in Finland the "Nurmi" culture is widely used, it seems reasonable to accept Dr. Nurmi's cost estimate.

4. Control Measures at the Processor's Level

There are approximately 90 poultry processing plants in Canada. Several actions could be taken to control the level of Salmonella in the processing plant, namely: clean poultry transportation crates, hygienic conditions in the plant, adding chlorine dioxide to the chilling water and irradiating poultry carcasses before selling to the wholesalers or resalers. The last two control measures are still at an experimental stage.

a) Clean transportation crates

Bird transportation crates are cleaned after unloading. Despite this, a study by Rigby et al.(23) revealed that more than 60% of the crates examined remained contaminated with Salmonella after washing. It has been shown that Salmonella-free birds before loading are infected at arrival at the processing plant(23). It therefore appears that washing and disinfecting the crates is not effective at the present time. Most crate washers are not designed to wash plastic poultry crates adequately before being disinfected. Frequently, washer pressure is lacking, the nozzles misdirected or inoperable, water is recycled and heavily laden with organic material. Actions can be taken to ensure proper washing and disinfecting of the crates (APPENDIX C).

A new cratewasher has been designed and is to be tested extensively. It is estimated that the cratewasher would cost $40,000 and that 1 per plant would be needed in medium sized and small plants and 2 in large plants (A.H. Bentley, personal communications). We assume 2 large plants and 88 medium/small ones. Total costs therefore would be: 92 x $40,000 = $3,680,000. This excludes the income from selling the old washers. Assuming a life expectancy of 10 years for the crate washers, and an interest rate of 12%, the washers would cost $626,600 per year.

b) Better Hygienic Conditions in the Processing Plant

A high level of hygienic conditions must be maintained in the processing plants (see APPENDIX C). To make educational audio-visuals available would cost $28,500.

We have assumed that these measures could be accomplished by two additional hours of labour per day. Additional costs would then be: 90 x $9 x 2 x 260 = $421,200.

c) Chlorine Dioxide in the Chilling Water

Adding chlorine dioxide to the processing plant's chilling water may reduce the number of *Salmonella* organisms on poultry carcasses. Thiessen(31), in his study on the effectiveness of chlorine dioxide on controlling Salmonella contamination, concluded that no salmonellae were detected in chill water containing 1.34 mg/l residual chlorine dioxide, nor were salmonellae isolated from broiler carcasses which had passed through chill water containing 1.34 mg/l residual chlorine dioxide. Also, no off tastes or off odours were encountered from treated broiler carcasses, although the broiler skin changed slightly from a slight pinkish white colour to a slight greyish white. Other advantages were reduced aerobic plate counts and an extended shelf life of 2.4 days.

Thiessen also calculated the cost of chlorine dioxide generating equipment, namely $20,417 per tank. Let us assume that 92 chilling tanks have to be transformed. Total installation costs would therefore be $1,878,364, or $319,786 per year, assuming a 10 year life expectancy of the equipment and a 12% interest rate. Cost of required chemicals are 0.30 cents per carcass. Accepting this as the average cost in the industry the chemicals would cost: $0.003 per carcass. 221,271,760 chicken carcasses x $0.003 = $663,815.

For turkey carcasses the costs would be: 13,485,211 x $0.003 = $40,456. Total cost of chemicals would be

$663,815 + $40,456 = $704,271. The total yearly cost would be $319,786 + $704,271 = $1,024,057. Agriculture Canada is currently studying the efficacy of adding chlorine dioxide to the chill water in processing plants.

d) Gamma-Ray Irradiation

In Canada, irradiation would be done through the AECL's (Atomic Energy of Canada Ltd.) industrial irradiators, which use gamma radiation emitting isostope cobalt - 60(8). This isotope has an entirely predictable emission rate of constant energy. The gamma rays emmitted by cobalt-60 pass through the product being irradiated, leaving no residual radio-activity.

The AECL has made a study(21) that examines the cost of treating poultry carcasses through irradiation.

Total domestic eviscerated poultry production is estimated at 471,000 t, which are processed through 90 plants. Two processors handle more than 20,000 t per year, 14 handle between 10,000 t and 20,000 t per year and the other 74 less than 10,000 t per year. The total capital investment for a plant, capable of processing 2,5 t/hr, will be between $1.2 and $1.5 million.

The annual operating costs of such a pallet irradiater should approximate $400,000 to $500,000. This includes amortization of the irradiating equipment, radiation shield and source on a straight line basis over 10 years. For a processor with a through-put capacity of 10,000 t per year, irradiation would cost between 4 and 5 cents per kilogram of processed poultry. These costs are based on a large processing capacity of 10,000 t per year. Let us estimate the average processing capacity of the small processor, who handles less than 10,000 t per year. We assume that the two largest processors each handle 30,000 t per year and the 14 large processors each 15,000 t per year. These two groups together would handle 270,000 t of poultry per year, an average of 16,875 t, leaving the other 74 processors 201,000 t or an average of 2,716 t per year. Should an irradiation facility be used of the same size as mentioned before, costing between $400,000 and $500,000 per year, then the average cost per kg. would be 15 to 18 cents per kg. for the small processor. One factor that should be further looked into is, whether the sizes of irradiators are continuous or not. In other words, is there an available size for each production capacity, or do irradiators come in specific sizes, for instance capable of handling 5,000 t, 10,000 t, 15,000 t, but nothing in between? Should the latter be the case, then even larger processors may have to allow for much spare capacity in their irradiator.

It must be emphasized that these calculations are based on an in-house type of set-up. For Canada that would mean 16 in-house irradiators. The other 74, smaller processors, would have to resort to a contract irradiator. Ouwerkerk(21) estimated that 10 service irradiators would be required. This would involve additional storage and transportation costs, but a service-type irradiator could possibly operate cheaper because of larger size. The geographical distribution of the smaller processors must be considered before we can make an estimate of these costs, but it would seem likely that the total cost to these processor would be higher than for the 16 larger processors. The contract-type irradiator could be economical for a cluster of smaller processors, but for isolated ones it could prove too expensive because of transportation costs. The 26 irradiators would cost the industry $11.7 million per year (26 x $450,000).

Operation of the irradiators would also require additional labour. If we assume 2 full-time operators per shift, 2 shifts and an hourly wage rate of $10 per person, the incremental labour costs would be
2 persons x 2 shifts x 8 hrs x $10 x 26 plants x

260 days = $2,163,200 per year. The total yearly costs to operate the irradiators would be $11.7 million + $2.16 million = $13.86 million.

Most contaminated poultry carcasses show relatively low levels of salmonellae, and the effectiveness of irradiation in reducing contamination is close to 100 percent. However, this does not rule out the possibility of cross-contamination after irradiation and great care must be continued at the retail and the consumption level.

From the above, we can make several conclusions:

- for large processors, irradiation of the final product appears economical;

- for small processors, the costs would be much higher, and for small, isolated processors they could be prohibitive;

- consumer acceptance is an unknown factor and more information is needed. Based on other countries' experiences, it is not impossible to gain the public's acceptance.

5. Control Measures in the Feed Industry

As mentioned, it is estimated that 6-8% of finished feed is contaminated with Salmonella. Because of the constant flow of feed to poultry, this means that the birds are often exposed to Salmonella infection. A Salmonella reduction program on carcasses, therefore, would be redundant if it would not control this flow of salmonellae into the industry. Because of the large number of feed mills and the fact that some farmers mix the feed themselves, it is difficult to control salmonellae in the feed industry. It is recognized, however, that feed ingredients are one of the main Salmonella sources in the feed industry, in particular meat meal from renderers. Care must be taken to control this source of contamination. In order to produce Salmonella-free rendered products, changes in the existing methods of operation will have to be introduced (see APPENDIX C). Making audio-visuals available that would educate the rendering industry is estimated at $10,500.

Finn(7) has estimated the cost to fumigate the feed mills every month. He calculated that it would cost $6.25 per tonne of feed. Using his method but adjusting for inflation, the current 1982 cost would be $3.8 per tonne, assuming that the feed mills are fumigated every 3 months (Bentley, personal communication). In 1982, the poultry industry consumed 1,216,094 tonnes of feed. Total costs would therefore be: $/t 3.8 x 1,216,094 t = $4,621,157. Education through the use of audio-visuals would cost $20,625.

Many broiler operations are linked to large feed companies. These companies often use heat treated, pelletized feed and this may explain why the Salmonella contamination of feed is rather low: 6%. It would be beneficial, however, to ensure that all feed ingredients, especially meat meal be Salmonella-free. If we apply the same $3.8 per tonne, to fumigate all rendered products, then this would cost 360,000 t x 3.8 $/t = $1.36 million. It is estimated that 70% of the meat meal goes into the poultry industry, which will bring the cost of providing clean rendered product to the poultry industry to $.96 million.

Other incremental costs would be difficult to estimate without a comprehensive survey of the industry.

6. Education of the Poultry Industry, Food-Service Sector Employees and Consumers

Since the outbreaks of salmonellosis are often the result of mishandling of food by consumers at home or in the food service establishments, as well as due to contamination during the stages of poultry production, benefits could be obtained if all groups are further sensitized to the danger of improper food handling.

a) Education of the Poultry Industry

Eight audio-visuals (AV) have been prepared by the Salmonella Coordinating Unit in Ottawa at a cost of $75,000. They are 15 minutes in duration and cover all segments of the poultry industry, namely: rendering, feed production; hatching egg production; hatching; broiler, turkey production; poultry processing; and an overview of Salmonella control throughout the poultry industry.

To estimate the cost of providing the poultry industry with these A.V.'s, we must include the cost of preparing the A.V.'s and the lost production incurred when viewing them. The lost production is estimated at $2.25 per worker, i.e. the average wage for 15 minutes. The number of workers is difficult to estimate for some industries. TABLE 6.1 gives an overview of these costs.

TABLE 6.1 COST OF EDUCATION OF POULTRY INDUSTRY

	COST OF A.V.	COST OF LOST PRODUCTION	TOTAL
Rendering Industry	$ 9,375	$ 1,125	$ 10,500
Feed Mills	$ 9,375	$11,250	$ 20,625
Hatching egg industry	$ 9,375	$ 5,625	$ 15,000
Hatcheries	$ 9,375	$ 5,625	$ 15,000
Broiler, turkey growers	$18,750	$22,500	$ 41,250
Poultry processing	$ 9,375	$19,125	$ 28,500
Overview	$ 9,375	$ -	$ 9,375
TOTAL			$140,250

In our analysis of the control measures, tables 7.1 and 7.2, the cost and effectiveness of educating the poultry industry is incorporated in the cost and effectiveness of cleaning-up the different segments of the industry. This because we feel that this type of education is the first step in improving the hygienic conditions at the plant level. The cost of implementing what was learned from the A.V.'s is generally reflected in additional labour required to provide a cleaner product.

Recently established regional sanitation awareness committees, organized by Agriculture Canada regional specialists, have provided a rapid means of making educational material such as the AV series on *Salmonella* control in poultry available to the poultry industry across Canada.

b) Education of the Food-Service Industry

Training of food-service employees on food safety must be encouraged. According to the Canadian Restaurant Association, there are approximately 600,000 people working in the food-service sector. If we assume that similar audio-visual displays can be made available to this industry for a cost of $25,000 and half of all employees see it once a year, it would cost $25,000 + $1,350,000 (lost production: $4.5 x 300,000) = $1,375,000. We have assumed that these A.V. would be 30 minutes in duration.

c) Education of the Consumer

Several actions can be taken to make educational material available to consumers:

- producing for the public, questions and answers sheets on Salmonella;

- producing pictorial material on safe food handling practices to place in public places, mail with family allowance cheques, place in airplanes, on buses, etc. Pamphlets can be made available for 5 cents a piece. Considering that there were about 7,000,000 households in Canada, it would cost $350,000 for printing. For those persons receiving an Income Security benefit, such as Family Allowance, Canada

Pension Plan benefit or Old Age Security pension, or an U.I.C. cheque, these fliers concerning food handling could be included at little extra cost;

- increase the amount of material taught to children on food safety;

7. Laboratory Costs

One cost that we have not mentioned thus far, is the laboratory costs that would ensue from the testing and monitoring of the poultry and poultry feed sector. Using Finn's(7) data and adjusting them for inflation, these costs could approximate $12 million per year. Although this is high, it is important that the levels of Salmonella contamination or infection in the different sectors be known. The laboratory costs are distributed as follows:

- imported poultry	$ 975,920
- domestic production	1,328,384
- domestic production of broiler chicken eggs	664,192
- poultry carcasses	552,286
- domestic feed production	2,407,866
- meat meal and feed ingredients	4,762,800
- imported rendered product	522,324
	$11,213,772

Finn(7) assumed that 0.5% of imported breeding stock eggs for broiler egg production would be tested, 0.5% of imported breeding stock chicks, 0.1% of commercial broiler eggs, 0.1% of imported commercial broiler chicks, 0.1% of imported eviscerated broiler carcasses, 0.1% of imported live market-weight broilers and 0.1% of imported cut-up chicken. Domestic production of chicken broilers and broiler chicken eggs would be tested at the same rate. Finn further assumed that every tenth tonne of domestic feed is tested and every tonne of rendered product, domestically produced or imported. In all cases he allowed for composite samples and for inclusion of transportation costs to the laboratory.

VII ECONOMIC ANALYSIS OF COSTS AND BENEFITS OF SALMONELLA CONTROL MEASURES

In part I we have analyzed the cost of *Salmonella* infections to humans and poultry. The total cost was estimated at $83,650,709 for human salmonellosis and $2,759,116 to the poultry industry. Since 25% of human salmonellosis is attributed to poultry (A.H. Bentley, personal communication), that sector is responsible for $21 million of the total cost. In part II we looked at the control measures that are available in the different sectors, from poultry to consumers, and attempted to put a dollar figure on these measures. Now, we will compare the costs and benefits of the different management options that are available. The main element still missing is the effectiveness of the control measures, i.e the degree to which the implementation of a control will reduce Salmonella infection/contamination in each sector. In most cases this effectiveness is very difficult to predict and expert opinion is often the rule. Where no Canadian expert opinion was found, the effectiveness used in the German Study(13) will be used or a range will be given.

To understand the total impact of a control measure, we must know to what degree the Salmonella infection/contamination in one sector is responsible for the infection/contamination in the next sector. Unfortunately, this information is not available and we must, therefore, estimate the intensity of these links. To evaluate this, we have constructed an infection chain model. The infection/contamination flows from feed to producer to processor. In this infection chain model we will base our estimate on following assumptions: the infection at the producer's level is caused by residual infection including non-hygienic methods, 65%; contaminated feeds, 25%; and salmonellae carrying chicks, 10%. At the processor's level, the Salmonella contamination is caused by conditions in the plant 20%; contaminated transportation crates, 25%; and infected birds at the grower's station level, 55%. We further assume that rendered products are responsible for 50% of the Salmonella contamination in feed.

TABLE 7.1 gives an overview of our assumptions and the degree to which they will reduce salmonellosis.

What is measured in the last column of the table is the percentage reduction in contaminated poultry carcasses at the moment they leave the processing plant. This is true for the control measures 1 to 9. The last 2 measures reflect the impact in reducing the prevalence of salmonellae at the time of consumption. We assume, therefore, similar to the German study(13), that there exists a one to one relationship (in percentage terms) between the reduction in contaminated poultry carcasses by salmonellae and the incidence of human salmonellosis caused by poultry. In other words, an 11% reduction in contaminated poultry carcasses will reduce human salmonellosis, caused by poultry, by 11%. This includes direct infection of humans by ingesting contaminated poultry and also salmonellosis caused by foods that were cross-contaminated by poultry.

TABLE 7.1 is an easy tool to evaluate the potential of the different control measures in reducing salmonellosis caused by poultry, based on the assumptions as presented in the row labelled "Assumptions". The effectiveness of each control measure is given in column 2. To calculate the total impact of a particular control measure, one traces the effectiveness through the different successive sectors. For example, clean hatching eggs reduce the number of _Salmonella_ carrying chicks by 40% x 10% = 4%. The 10% is the perentage that Salmonella carrying chicks are responsible for the prevalence of salmonellae within the producer's sector. Poultry normally ends up in the processing sector. We assume, based on expert opinion, that 55% of all salmonellae here is caused by infected birds from the producing sector. Clean hatching eggs will therefore reduce the number of contaminated carcasses by 40% x 10% x 55% = 2.2%. This 2.2% is also the percentage reduction in human salmonellosis that is caused by poultry.

Following is an overview of the impact of the control measures in reducing human salmonellosis and in improving the productivity at the grower's level where applicable. The benefits accrueing from the reduced incidence of salmonellosis are then calculated for each control measure. We should emphasize that when we use "clean" in table 7.1, we do not only mean "free of dirt", but also "disinfected".

1. Production of Clean Hatching Eggs

Total incremental costs for producing clean hatching eggs was estimated at $2.93 million. The German study(13) used 40% as the effectiveness of similar measures. Using our infection chain model, a 40% reduction at the hatchery level would mean a 2.2% reduction in contaminated carcasses level (40% x 10% x 55%). In terms of costs, it would reduce human salmonellosis by 2.2% or $21 million x

TABLE 7.1 TOTAL EFFECTIVENESS OF DIFFERENT CONTROL MEASURES

		FEED	PRODUCER			PROCESSOR			
	EFFECTIVENESS	RENDERERS	SALMONELLA CARRYING CHICKS	RESIDUAL CONTAMINATION	FEED	TRANSPORTATION CRATES	PLANT CONDITIONS	INFECTED BIRDS	TOTAL IMPACT
ASSUMPTIONS		50%	10%	65%	25%	25%	20%	55%	
1 Clean hatching eggs	40%		10%					55%	2.2 %
2 Clean feed industry	80%				25%			55%	11 %
3 Clean rendering industry	80%	50%			25%			55%	5.5 %
4 Clean grower barns	40%			65%				55%	14.3 %
5 Nurmi culture	75%		10%	65%	25%			55%	41.25%
6 Clean poultry transportation crates	100%					25%			25 %
7 Chlorine dioxide	50%								50 %
8 Irradiation	100%								100 %
9 Clean processing ing industry	80%						20%		16 %
10 Education of homemakers	5%								5 %
11 Education of food service industry	16%								16 %
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	

.022 = $462,000, and would improve productivity in the poultry sector by 4% (40% x 10%), creating a benefit of $2,759,116 x .04 = $110,365. Total benefits would be $462,000 + $110,365 = $572,365. It must be emphasized that these results would change dramatically should different assumptions be accepted.

2. Control Measures in the Feed and Rendering Industries

We have estimated that fumigation of the feed mills would cost $4.6 million, and $0.96 million for the rendering industry. Should the other hygienic conditions be adhered to in the mills and during transportation, then the effectiveness could be very high. Let us verify an effectiveness rate in the feed industry of 80%. This would reduce human salmonellosis by 11%, (80% x 25% x 55%), $2.31 million, and would reduce costs caused by salmonellae to poultry by 20%, $.56 million, for a total financial benefit of $2.87 million. For the rendering industry the comparable figures would be: 80% x 50% x 25% x 55% = 5.5, $1.16 million, and 80% x 50% x 25% = 10%, or $.28 million. Total financial benefits would therefore be $1.44 million.

3. Clean-Up and Disinfection of the Grower Barns

We have estimated that it would cost the poultry industry $5.66 million to improve the hygienic conditions in the grower barns. This includes the cost of providing

Salmonella control education to this sector. Most of this cost would be in the form of increased labour cost. The effectiveness of these measures is set at 40% in agreement with the German study(13). The 40% effectiveness of this control action would reduce human salmonellosis by 40% x 65% x 55% = 14.3%, for a benefit of $3.0 million. It would also improve productivity for a value of $2.76 million x 40% x 65% = $.72 million. Total benefits would thus be: $3.0 million + $.72 million = $3.72 million. Here it must also be mentioned that the better hygienic conditions could have a greater impact on productivity because of a reduction in other poultry diseases.

4. The Nurmi Concept

Whereas the 3 above mentioned control measures have a direct impact on the source of Salmonella infection, the use of the "Nurmi Culture" would mainly impact on the effects, although it would reduce residual infection in the grower barns in subsequent time periods. It has been shown that ingestion of the gastro-intestinal flora of adult poultry by young chicks can greatly increase the resistance to Salmonella infection. The effectiveness of this method is not accurately known since it depends at what age the young birds are given the culture and the infectious doses to which the birds are exposed. The Nurmi concept would impact on all three sources of contamination/infection in the producer's sector, and would have a cumulative impact within this sector of 100% (10% + 65% + 25%). A 75% effectiveness would reduce human salmonellosis by 75% x 100% x 55% = 41.25%, which would mean a monetary value of $21 million x 41.25% = $8.66 million. Poultry productivity would be increased by a value of $2.1 million. Total benefits would be $8.66 million + $2.1 million = $10.76 million.

5. <u>Adequate Cleaning and Disinfection of Poultry Crates</u>
Experts feel that properly cleaned and disinfected poultry crates could reduce <u>Salmonella</u>-contamination at the processors level by 25% (A.H. Bentley, Personal Communication). A 25% reduction at this level would mean a 25% reduction of human salmonellosis, a benefit of $21 million x 25% = $5.25 million. There could be additional spin-off effects at the producer level because contaminated crates can return salmonellae to the farm where they could infect the other flocks. The above analysis assumes that the poultry crates can be 100% <u>Salmonella</u>-free.

6. <u>Use of Chlorine Dioxide in Chill Water</u>
This method is currently under study. At 50% effectiveness, the benefits in terms of human salmonellosis reduction would be 50% x $21 million = 10.5 million. Other benefits according to Thiessen are, reduced bacterial count and increased shelf life(31).

7. Irradiation of Processed Poultry

This method is 100% effective, and assuming all poultry is treated would create benefits in terms of a reduction of human salmonellosis of $21 million. Other benefits are: a reduction in other bacteria and increased shelf life.

8. Clean Poultry Processing Industry

Education of the poultry processing industry, which would result in better hygienic conditions in the plant, would reduce human salmonellosis by 80% x 20% = 16%, or $21 million x 16% = $3.36 million.

9. Education of the Homemaker

To inform consumers would cost $350,000 and it could be an effective way in preventing cross-contamination in the home kitchen. If the effectiveness is 5% then the benefits would be 5% x $84 million = $4.2 million. Since education of the home maker would reduce salmonellosis caused by all contaminated foods and not only by poultry, the benefits derived from education must be evaluated using $84 million, the total cost of human salmonellosis, rather than the $21 million used in the previous control measures. It may be advisable to inform the consumer more than once per year concerning Salmonella contamination in the home kitchen.

10. Education of the Food-Service Industry

To educate all food-service employees every two years would cost $1.38 million. The effectiveness has been estimated at 16%, in the German study (Krug 1983). The benefits to the Canadian population would therefore be 16% x $84 million = $13.44 million.

VIII BENEFIT/COST ANALYSIS

We will now compare the cost versus the benefits of the different control measures. It should first be mentioned that our analysis is based on several assumptions and it must be kept in mind that the results are very sensitive to the assumptions that are made. We will present the analysis in table form for easier comparison. The number in parentheses is the estimated effectiveness, the other ones are for sensitivity analysis only. This allows us to determine to what degree the outcome would change, should different assumptions be used. Once again, we should stress the fact that "clean" also includes the meaning "disinfected" in table 7.2, in other words, not only free of dirt but also free of harmful bacteria, viruses, etc.

TABLE 7.2 COST-BENEFIT COMPARISON OF SALMONELLA CONTROL MEASURES

CONTROL		COST $000,000	BENEFIT[1] $000,000	OTHER BENEFITS
1. Clean hatching eggs and clean hatchery	(40%)	$ 2.93	$ .57	- Reduction in other poultry diseases
	20		.29	
	80		1.14	
2. Clean feed	(80)	4.6	2.87	
	20		.72	
	40		1.44	
3. Clean rendered products	(80)	.96	1.44	
	20		.36	
	40		.72	
4. Clean-up grower barns	(40)	5.66	3.72	- Reduction in other other poultry diseases
	20		1.87	
	80		7.46	
5. Nurmi culture	(75)	19.26	10.76	
	25		3.59	
	50		7.17	
6. Clean poultry crates	(100)	.63	5.25	- Reduction in other bacteria
	50		2.63	
7. Use of chlorine dioxide	(50)	1.02	10.50	- Reduction in other pathogens, increased shelf life (2.5 days)
	25		5.25	
	75		15.75	
8. Irradiation	(100)	13.86	21.00	- Reduction in other pathogens, increased shelf life.
9. Clean poultry processing	(80)	.45	3.36	- Reduction in other bacteria
	20		.84	
	40		1.68	
10. Education of the homemaker	(5)	.35	4.20	- Reduction in other bacteria, and in salmonellosis by other foods
	10		8.40	
	20		16.80	
11. Education food service sector	(16)	1.38	13.44	- Reduction in other bacteria and in salmonellosis by other foods
	8		6.72	
	32		26.88	

---

[1] The benefits refer to the reduction in human salmonellosis and associated costs and/or an increase in the productivity in the poultry sector.

It should be emphasized that the results are based, to a large extent, on expert opinion. To generate "harder" data more empirical evidence is necessary. We should also like to draw the attention to another aspect of the analysis. The benefits and cost are calculated for a one-year time period. Implementation of control measures should reduce the incidence of salmonellosis and thus the costs caused by the disease in subsequent periods. On the other hand, the control costs would largely remain the same from year to year. In our analysis we have also ignored the effects of some vectors of infection on each other. Contaminated feed, for instance, was assumed to be responsible for 25% of the infection in the grower barns. It should be realized, however, that "clean" feed in period 1, would reduce the prevalence of salmonellae at the producer level in period 1, but it would also reduce the residual contamination in the barns during period 2 which would benefit the industry. The same type of analysis would hold for clean hatching eggs, clean poultry crates and the Nurmi culture. In short, we have not really taken account of the infection and contamination dynamics within the poultry system.

The Salmonella Coordinating Unit has been involved in or associated with several research projects directed at finding practical measures to control undesirable bacteria in poultry. These projects are as follows: disinfection of broiler barns, feeding bacterial (Nurmi) cultures to day-old chicks, chlorination of poultry drinking water, rendered feed ingredients, irradiation of poultry meat, chlorine dioxide in poultry processing chill-water, development of a new crate washing system, <u>Salmonella</u>-free primary breeder flocks, and sanitary transportation of feeds. Completion of these projects should provide us with more accurate data and should improve the accuracy of the estimated costs of the control programs.

Another important aspect which must be mentioned is the possibility of using several control measures in the same or in different sectors. Let us illustrate this. Suppose that following control measures are implemented.

	COSTS ($000 000)
- clean rendered product	$ .96
- clean-up grower barns	5.66
- clean poultry crates	.63
- use of chlorine dioxide	1.02
TOTAL	$8.27

The total cost of these four measures are estimated at $8.27 million. The benefits are not cumulative because implementation of one measure will reduce the prevalence of salmonellae in subsequent sectors and hence the benefits that would be obtained by implementing a control measure in the latter sector.

IX CONCLUSIONS

It is difficult to draw straightforward conclusions from the analysis. However, it appears that control measures taken closer to the point of food intake, are a more effective way of reducing human salmolellosis. This is certainly the case in the short run. In the long run, it seems imperative that measures are also taken at the beginning of the infection chain. Failure to do so would allow the poultry industry to remain contaminated and/or infected with salmonellae. To control salmonellae and to reduce salmonellosis in the long run, the source of infection and contamination should be attacked and, if possible, eliminated.

We believe that we have provided a framework that will allow choosing the most effective way of reducing human salmonellosis caused by poultry, once more information on the effects of control measures becomes available.

GLOSSARY OF TERMS

Acute enteritis: A short and relatively severe inflammation of the intestine.

Anorexia: Lack or loss of the appetite for food.

Chronic Enteritis: Inflammation of the intestine persisting over a long period of time.

Contamination: Presence of an organism on the surface of poultry meat or other product.

Infection: The presence of salmonellae in the living animal or bird with or without the production of clinical signs of disease.

Pathogens: Any disease-producing microorganisms or material.

Peracute Septicaemia: Excessively acute or sharp systemic disease associated with the presence and persistence of pathogenic microorganisms or their toxins in the blood.

Salmonellae: Bacteria of the genus *Salmonella* that can cause food poisoning.

Salmonellosis: Presence of clinical signs of disease due to infection with a *Salmonella* organism.

Serotype: A subdivision of bacteria (here *Salmonella*) distinguished on the basis of antigenic composition.

APPENDIX A

Estimated Cost of Salmonellosis in Humans

To estimate the cost of Salmonella poisoning in people we must first distinguish between the reported cases and the non-reported cases.

In 1978, 8474 cases of human salmonellosis were identified at the Enteric Reference Centre, Department of National Health and Welfare. Experts believe that this number represents only between 1 and 3 percent of the real incidence. For purpose of this study we have accepted the average percentage (2%) and hence, costs were calculated using 423 700 - 8474 = 415 226 non-reported cases.

During the same year, 1978, Statistics Canada reported 1625 hospitalized cases of salmonellosis; we assume that all cases were identified at the E.R.C. (Statistics Canada, Cat. 82-206)(29).

To calculate the costs associated with Salmonella poisoning, we have distinguished among 3 categories:

- hospitalized cases: 1625 (Statistics Canada, Cat. 82-206)(29)
- reported, non-hospitalized cases: 8474-1625 = 6849
- non reported, non-hospitalized cases: 415 226(24)

Several costs can be identified, and with analogy with a West-German study on Salmonella(13) we have calculated following costs for each category:

- Hospital and Medical costs
- Loss of productive output - workers
  - housewives
- Loss of leisure
- Loss of consumption
- Investigation costs
- Loss of life

In order to allow a more detailed and correct calculation we have analyzed the costs in each category for different demographic and/or economic groups. These groups are: children from age 0 to 14; males from 14-64 years of age and a subgroup males 14-64 who are not in the work force; females age 14-64 and a subgroup housewives; persons 65 years and older and a subgroup persons 65 years and over who are still in the workforce. It must be mentioned that the subgroups are not always separately identified.

Following is a detailed calculation of the costs and the underlying assumptions. We have used 1978 data, because that was the latest year for which all data were available.

1) Hospital and Medical Costs (data are specifically for Salmonellosis)

Assumptions:

- number of cases: 1625, divided in age group according to the morbidity tables 82-206 (Stat Can. 1978)(29);
- average stay in hospital, per age group: per morbidity tables (Statistics Canada, Cat. 82-206);
- 7 days of convalescence after stay in hospital;
- cost per day of hospitalization: $246.50 (Statistics Canada: Hospital Statistics, preliminary annual report, 1982-83);
- cost of physicians' services per case (1982 $) $27.00 (unweighted Canadian average);
- consultation with specialist: $75.00;
- lab test: isolation plus sero typing: $50;
- number of lab test: 3 for hospitalized cases
  2 for reported, non-hospitalized cases
  0 for non-reported cases;
- medication: as a rule, no antibiotics are given as they may prolong the disease.

TABLE A.1 HOSPITALIZATION COSTS (in 1982 dollars)

AGE GROUP	CASES	AVERAGE STAY IN HOSPITAL	AVERAGE COST PER CASE	TOTAL COST
0-14	757	9.2	$2,268	$1,716,876
Male 15-64	357	8.5	$2,095	$ 747,915
Female 15-64	384	8.7	$2,145	$ 823,680
65 +	127	16.0	$3,944	$ 500,888
	1,625			$3,789,359

As a group, children are over-represented. This is mainly because the effects of salmonellosis on children are more severe and therefore doctors are more likely to treat salmonellosis symptoms as serious, requesting laboratory examinations.

TABLE A.2 MEDICAL COSTS FOR HOSPITALIZED CASES (in 1982 $)

AGE GROUP	CASES	HOSPITALIZATION COSTS/CASE	MEDICAL COST PER CASE	TOTAL MEDICAL COSTS
0-14	757	2,268	$252.00	$1,907,640
M. 14-64	357	2,095	$252.00	$ 837,879
F. 14-64	384	2,145	$252.00	$ 920,448
65 +	127	3,944	$252.00	$ 532,892
	1,625			$4,198,859

The medical costs were calculated as follows:

- cost of complete examination	:	$ 27.00
- 3 lab tests	:	$150.00
- consultation with specialist	:	$ 75.00
		$252.00

Since the 65 + group stays in the hospital for a much longer period, it was assumed that they would receive twice the amount of medication that the other groups received.

TABLE A.3 MEDICAL COST PER REPORTED, NON-HOSPITALIZED CASE

AGE	CASES	MEDICAL COST PER CASE	TOTAL COST
0-14	3,219	$127	$408,813
M. 14-64	1,507	$127	$191,389
F. 14-64	1,644	$127	$208,788
65 +	479	$127	$ 60,833
	6,849		$869,823

The medical costs were assumed to be as follows:

- cost of complete examination	:	$ 27.00
- 2 lab test	:	$100.00
		$127.00

Since no distribution over age groups is available, we have assumed it is the same as for the hospitalized cases: age group 0-14: 47%; M. 14-64: 22%; F. 14-64: 24% and 65 +: 7%.

We have assumed that the non-reported cases of salmonellosis (415226)are distributed over the age group according to the respective groups' relative populations:

0-14	24.7 %	102,561
M. 14-64	33.2 %	137,855
F. 14-64	33.3 %	138,270
65 +	8.8 %	36,540

However, since most of these cases would not visit a doctor, no medical cost are attributed to this category.

Total medical and hospitalization cost can therefore be summarized:

- for hospitalized cases	:	$4,198,859
- for reported, non-hospitalized	:	$ 869,823
TOTAL		$5,068,682

2) Loss of Productive Output

Loss of productive output must be considered as an indirect cost. For each working day that is lost, a certain amount of economic output is not realized and society as a whole incurs a loss. Although, in certain cases, absence of a worker does not necessarily mean that his or her work is not performed, for purpose of our analysis we assume that this is the case. Economists generally agree that the economic loss can be measured by the gross salary the worker in question receives for the duration of his absence.

The time that a worker is ill, is not all working time and we have therefore, adjusted the duration of the illness to working days. The number of missed working days is equal to the duration of illness x .63. The factor .63 was derived at by dividing the number of working days in a year by 365. (365 days - 104 weekend days - 20 holidays - 10 statutory holidays = 231 ; $\frac{231}{365}$ = .63)

Since all ill persons in a group are not in the workforce and productive output loss is only realized when a worker is ill, we have multiplied the duration of the salmonellosis for each category by the respective employment/population ratio. The employment/populations ratio was obtained from Statistics Canada publications (Stats Can. 71-001, 1978)(28).

0-14	0%
M. 14-64	77.7%
F. 14-64	49.5%
65 +	8.7%

The average salary for the different age groups was also obtained from Statistics Canada data (Stats Can. 13-206)(27). The average salary for persons 65 + who are still working was assumed to be the same as for the 55-64 age category. Although children under 14 years of age are not working, productive output is lost when they are ill because we assumed that one parent will stay at home in such cases. We further assumed that half of the working women have children in the 0-14 age category. The women's employment/population ratio is therefore halved in order to calculate lost production due to children's illness. The salary, measure for productive output, is taken as the female 14-64 group. We realize that in many cases it would be the man who would stay at home, but by taking the F. 14-64 data we run less risk of overestimating the productive output loss in the 0-14 group.

TABLE A.5 HOSPITALIZED CASES (1978 $)

AGE GROUP	CASES	DAYS ILL	WORKING DAYS	AVERAGE DAILY SALARY	COSTS
0-14	757	16.2	2.5	$42	$ 79,485
M. 14-64	357	15.5	7.6	$79	$214,343
F. 14-64	384	15.7	4.9	$42	$ 79,027
65 +	127	23	1.3	$67	$ 11,062
	1,625				$383,917

Example of a calculation of "working day":

0-14 group: days ill x (yearly number of working days/365) x (employment/population in the F. 14-64 group)

i.e.: 16.2d. x (231/365) x (49.5/2) = 2.5 days

TABLE A.6 REPORTED, NON-HOSPITALIZED CASES

AGE GROUP	CASES	DAYS ILL	WORKING DAYS	AVERAGE DAILY SALARY	TOTAL COSTS
0-14	3,219	7	1.1	$42	$148,718
M. 14-64	1,507	7	3.4	$79	$404,780
F. 14-64	1,644	7	2.2	$42	$151,906
65 +	479	7	0.4	$67	$ 12,837
	6,849				$718,241

TABLE A.7 NON-REPORTED CASES

AGE GROUP	CASES	DAYS ILL	WORKING DAYS	AVERAGE DAILY SALARY	COSTS
0-14	102,561	3	0.5	$42	$ 2,153,781
M. 14-64	137,855	3	1.5	$79	$16,335,817
F. 14-64	138,270	3	0.9	$42	$ 5,226,606
65 +	36,540	3	0.2	$67	$ 489,636
					$24,205,840

Total loss of productive output: $383,917 + $718,241 + $24,205,840 = $25,307,998.

We have now calculated the tangible indirect cost, loss of productive output due to salmonellosis. We have, however, left out one important category, namely housewives. To determine the output loss due to salmonellosis in this group we must make several assumptions. We have valued their output as the equivalent to the income in the retail trade which is the lowest average weekly wages and salaries, by industrial division, based on the 1960 standard industrial classification in 1982, i.e. $236.14 per week or $236.14 ÷ 7 = $33.73 daily. We divide by 7 rather than by 5 because they work 7 days a week.

The number of housewives is assumed to be: total female population, age 14-64, less women in the work force less women unemployed. 7.846 million-(3.887 million + 379 thousand) = 3.580 million or 45.6% of the F. 14-64 group. We further assume that when ill, they still do half their regular work. When hospitalized, there is a total loss of productive output.

TABLE A.8 LOSS OF PRODUCTIVE OUTPUT FROM HOUSEWIVES

CATEGORY	CASES	DAYS ILL AND/OR IN HOSPITAL	WORKING DAYS MISSED	TOTAL COST
hospital	384	7 + 8.7	1.6 + 4	$ 72,533
reported, non-hospitalized	1,644	7	1.6	$ 88,723
non-reported	138,270	3	0.7	$3,264,693
				$3,425,949

Example of calculation of working days missed:

- hospital: - 7 (days convalescence at home) x 0.456
  x 0.50 (they still do half their regular work)
  = 1.6 days
  - 8.7 (days in hospital) x 0.456 = 4 days

3) Loss of Leisure

Whereas the previous categories, medical costs, loss of productive output and even output loss for housewives are relatively non-controversial, the loss of leisure is not quite so easy to evaluate. Many analysts would agree that a cost should be attached to this loss of leisure. Indeed, should one think of overtime as infringing upon leisure time and therefore being remunerated at the value society puts on leisure time, then leisure time should be calculated at 150% of regular salary. We do not intend to go this far, but we will evaluate the loss of leisure at the same rate as the loss of productive output. Although the cost is indirect and intangible, we feel it should be included in a cost/benefit analysis. The "Trier-study"(13) has calculated loss of leisure by allocating 5 hours of leisure to each working day. We will follow this line and further assume 12.5 hours of leisure on a non-working day. To calculate the hourly rate, we divide the average daily salary in each working category by 7.5, the average number of hours in a working day. Leisure time for women and men not in the work force is calculated at 5 hours per day, assuming that they work 7 days a week. For the 65 + category is was necessary to distinguish between 65 + still working and those no longer working. Those working are treated like the other working groups and the others are assumed to have 12.5 hours of leisuretime per day, evaluated at the average hourly income of persons 65 and over i.e. $1.317 per hour (Stats Can. 13-206)(27).

In summary, the average hourly rate at which the different categories are remunerated:

Working males 14-65	:	$10.53
Working females 14-65	:	$ 5.60
Working 65 +	:	$ 8.93
Non-working males 14-65	:	$ 4.50
Non-working females (housewives)	:	$ 4.50
Non-working 65 +	:	$ 2.39

TABLE A.9 HOSPITALIZED CASES

AGE GROUP	CASES	DAYS	WORKING DAYS	LEISURE DAYS	LEISURE HOURS	COST
NWM 14-64	80	15.5	15.5	-	77.5	$ 27,900
M 14-64	277	15.5	9.8	5.7	120.25	$350,746
WF 14-64	190	15.7	9.9	5.8	122.0	$129,808
NWF 16-64	194	15.7	15.7	-	78.5	$ 68,531
NW 65 +	116	23.0	-	23	287.5	$ 79,707
W 65 +	11	23.0	14.5	8.5	178.75	$ 17,559
						$674,251

In this table we have adjusted the number of cases by the employment/population ratio in the respective age groups. We have assumed no loss of leisure because of illness in children between 0-14 years of age. Non-working males, age 14-64, are considered the same as housewives. Both categories include unemployed persons. We assume 5 hours leisure per day and all days are working days.

TABLE A.10 REPORTED, NON-HOSPITALIZED CASES

AGE GROUP	CASES	DAYS	WORKING DAYS	LEISURE DAYS	LEISURE HOURS	COST
NWM 14-64	336	7	7	-	35	$ 52,920
M 14-64	1,171	7	4.4	2.6	54.5	$ 672,019
WF 14-64	814	7	4.4	2.6	54.5	$ 248,432
NWF 16-64	830	7	7	-	35	$ 130,725
NW 65 +	437	7	-	7	87.5	$ 91,388
W 65 +	42	7	4.4	2.6	54.5	$ 20,441
						$1,215,925

TABLE A.11 NON-REPORTED CASES

AGE GROUP	CASES	DAYS	WORKING DAYS	LEISURE DAYS	LEISURE HOURS	COST
NWM 14-64	30,742	3	3	-	15	$ 2,075,085
M 14-64	107,113	3	1.9	1.1	23.25	$26,223,671
WF 14-64	68,444	3	1.9	1.1	23.25	$ 8,911,409
NWF 14-64	69,826	3	3	-	15	$ 4,713,255
NW 65 +	33,361	3	-	3	37.5	$ 2,989,980
W 65 +	3,179	3	1.9	1.1	23.25	$ 660,032
						$45,573,432

Total leisure costs would be $47,463,608. As mentioned, this is an indirect intangible cost, but we feel that is is justified to include this category.

4) Investigation Costs

Our estimate of the costs of inspection by health officials of a Salmonella outbreak, is based on the actual costs as compiled by Todd (Dr. E.C.D. Todd, Bureau of Microbial Hazards, Health Protection Branch, Health and Welfare Canada; unpublished paper). We have calculated the average investigational cost in 6 outbreaks of Salmonella in Canadian Food Services establishments and hospitals at $47 per person. Extrapolating this average over all human isolated cases, 8474 in 1978, provides and estimate of the total investigational costs of $398,278.

5) Value of Loss of Life

In 1977, although salmonellosis was never indicated as the sole cause of death, it was mentioned in 7 cases(29). There is significant controversy among economists as to how best value loss of life. Two main methods prevail. First, the Human Capital approach values life equal to the future production potential, usually calculated as the discounted, present value of expected future earnings. This value is relatively easy to calculate, but many feel that the method is morally not acceptable. The second method, the Willingness-To-Pay approach attempts to measure the value that an individual attaches to his/her own life by evaluating how much a person would be willing to pay to extend the expected life span. This method, although prefered on theoretical ground by most analysts, is difficult to calculate and has lead to large variations in the estimated value of life. Landefeld et al.(14) have used a combined approach, the Adjusted Willingness-To-Pay/Human Capital estimates which we will use here.

Since mortality, involving salmonellosis, mostly occurs with infants and the elderly, we have used the average Adjusted Willingness To Pay/Human Capital estimates between the age groups 1-4, male and female, and 70-74, male and female.

In 1982 canadian dollars, our estimate of the value of life is then $567,484 per life. We assume that salmonellosis is a 50% contributing factor in the mortality cases. Total loss of life, due to salmonellosis would therefore be $567,484 x 7 x 50% = $1,986,194.

6) Loss of Consumption

Because of salmonellosis, afflicted persons will tend to eat less than normally. This reduction in consumption expenditure will shrink gross national expenditure and as such could be considered as a cost. The German study assumed that, during the illness, consumer expenditures would be reduced by 50 percent. We have narrowed this to mean consumer expenditures on food, beverages and tobacco. According to the "Handbook on food expenditures, prices and consumption", expenditure on food and beverages in 1980 were $34,381 million for a total population of 24.5 million(9).

Since the data for 1980 were the most recent ones available, we have adjusted the 1980 figures to 1982, by multiplying by the retail food price index, which was obtained from the same source. Population was estimated at 24.5 million. The average expenditure per person on food, beverages and tobacco was thus estimated as $41,042 million ÷ 24.5 million = $1,675 per person per year or $4.6 per day per person.

Total cost due to loss of consumption can thus be calculated as follows:

a. Hospitalized Cases

AGE	CASES	DAYS ILL	COST AT $2.3 PER ILL PERSON/DAY
0-14	757	16.2	$28,206
M. 14-64	357	15.5	$12,727
F. 14-64	384	15.7	$13,866
65 +	127	23.0	$ 6,718
b. Reported, Non-Hospitalized Cases			
	6,849	7	$110,269
c. Non-Reported Cases			
	415,226	3	$2,865,059
TOTAL			$3,036,845

It should be mentioned here that the loss of consumption is a "distributional cost" i.e. money not spent on food now because of illness will presumably be spent later. This "postponed" expenditure can therefore not be added to the total economic cost of salmonellosis.

7) Economic Loss to Food Businesses

Another factor that can have an important financial impact, is the repercussion an outbreak of salmonellosis can have on a restaurant where the food was mishandled. The lost earnings to that business can be substantial. The same holds for the food processor should his product be implicated. Todd (Todd, unpublished paper) has looked at these costs in several outbreaks. The costs vary widely and in the case of salmonellosis they can range from a $10,000 to $33 million. We have estimated this cost by taking the average loss experienced by 5 food service establishments as compiled by Todd. The costs per outbreak was approximately $166,000. In 1977, 15 outbreaks of salmonellosis were caused by mishandling of food in food service establishments. Total cost for that year would therefore be $2,490,000. These costs are of a distributional nature since business lost by an establishment that was involved in a salmonellosis outbreak will, to a large degree, be picked up by another food service establishment. For this reason these costs should not be included in calculating the benefit/cost ratio. However, it should be borne in mind that the financial impact on the food processor or supplier is very real and can indeed cause the closure of the establishment.

8) Other Costs

Although we acknowledge the existence of other costs, such as pain and suffering experienced by the afflicted persons, we have not included them in our analysis because of the uncertainty concerning the methods to evaluate such costs. There is also the suffering of other persons, close to the ill persons, which could be taken into consideration. This category could especially be important in the cases where children are the victims, and where considerable concern and anxiety can exist among the parents and other family members of the ill child.

Another cost category which is sometimes calculated is the transportation expenditures and time of persons visiting hospitalized persons(5).

We do realize that these costs exists, but because of the surrounding controversy and practical problem in calculating them we decided against including them in our cost estimates.

Legal costs may also be involved, but data are not obtainable because many of these cases are settled out of court.

It is fair to say, therefore, that the above identified and calculated costs are minimum values.

TABLE A.12 SUMMARY OF COSTS (1982 canadian dollars)

	HOSPITALIZED	REPORTED, NON-HOSPITAL	NON-REPORTED	TOTAL	%
HOSPITAL & MED. COST	4,198,859	869,823	0	5,068,682	6.1
LOSS OF PRODUCTIVE OUTPUT	456,450	806,964	27,470,533	28,733,947	34.3
LOSS OF LEISURE	674,251	1,215,925	45,573,432	47,463,608	56.7
INVESTIGATION COSTS	76,375	321,903	-	398,278	0.5
LOSS OF LIFE	1,986,194	-	-	1,986,194	2.4
TOTAL	7,392,129	3,214,615	73,043,965	83,650,709	100
AVERAGE	$ 4,549	$ 469	$ 176	$ 197	

We should mention that the number of cases that we used in these calculations were based on the fact that the reported cases represent but 2 percent of the real incidence of human salmonellosis cases.

the lower bound (3%) would be:

1,625 reported, hospitalized cases : $ 7,392,129
6,849 reported, non-hospitalized cases : $ 3,214,615
273,993 non-reported cases : $ 48,199,136

$ 58,805,880

the upper bound would be : $ 7,392,129

1625 reported, hospitalized cases: : $ 3,214,615

6849 reported, non-hospitalized cases : $147,578,610

838,926 non-reported cases : $158,185,354

APPENDIX B

Calculations of Costs Caused by Salmonella in the Canadian Poultry Sector

We will compare two methods to calculate the economic costs caused by Salmonella in the Canadian poultry sector. The first method is based on the German study's assumptions; the second one on P. Finn's analysis.

Our data are 1983 data, obtained from diverse sources.

a) Production

Canadian domestic chicken production, 1983 : 376,162,000 kg.
Canadian domestic turkey production, 1983 : 95,745,000 kg.
source: Market commentary, Dec. 1983

1 kg. live chicken = 0.735 kg. eviscerated chicken
1 kg. live turkey = 0.82 kg. eviscerated turkey
source: CMAD, poultry sector.

b) Prices

Average price to producers for:
- live chicken: 110¢/kg. (Ontario)
- live turkey: 140¢/kg. (Ontario)

Average price to wholesaler
- eviscerated chicken: 200 ¢/kg. (Ontario)
- eviscerated turkey: 230 ¢/kg. (Ontario)

source: Agriculture Canada, Market Commentary, December 1983

- price of feed:
  - chicken: $251 per ton
  - turkey: $271 per ton

source: livestock feed board. The price is average for December 1983 and December 1982, for different kind of rations (starter, grower, finisher).

c) Weight

Average live weight
- broiler 1.7 kg.
- turkey 7.1 kg.

d) Feed Requirements to Maturity

- broiler: 3.4 kg.
- turkey: 20.7 kg.

Method 1

The German study assumed removal of poultry, caused by Salmonella, at the producer level of between 0.5 and 1.26% of the total number of animals. At the processors' level, they assumed that 1/3 of all rejection of animals was due to Salmonella i.e. 1/3 of between 0.5 and 1%. If we apply these assumptions to the Canadian situation, we derive the following costs:

a) Producer's Level:

- chicken:
  (376,162,000 kg ÷ 0.735) x 0.005 x 1.1 $/kg = $2,814,818
  (376,162,000 kg ÷ 0.735) x 0.0126 x 1.1 $/kg = $7,093,340
  $9,908,158
  average: $9,908,158 ÷ 2 = $4,954,079

- turkey:
  (95,745,000 kg ÷ 0.82) x 0.005 x 1.4 $/kg = $ 817,335
  (95,745,000 kg ÷ 0.82) x 0.0126 x 1.4 $/kg = $2,059,684
  $2,877,019
  average: $2,877,019 ÷ 2 = $1,438,510

b) Processor's Level:

- chicken:
  376,162,000 kg ÷ 0.995 x 1/3 (0.005) x 2.0 $/kg = $1,260,174
  376,162,000 kg ÷ 0.9874 x 1/3 (0.01) x 2.0 $/kg = $2,539,747
  $3,799,921
  average: $3,799,921 ÷ 2 = $1,899,961

- turkey:
  95,745,000 ÷ 0.995 x 1/3 (0.005) x 2.3 $/kg = $ 368,867
  95,745,000 ÷ 0.9874 x 1/3 (0.01) x 2.3 $/kg = $ 743,412
  $1,112,279
  average: $1,112,279 ÷ 2 = $556,140

		LOW	HIGH	AVERAGE
producer:	chicken	2,814,818	7,093,340	4,954,079
	turkey	817,335	2,059,684	1,438,510
processor:	chicken	1,260,174	2,539,747	1,899,961
	turkey	368,867	743,412	556,140
Total		$5,261,194	$12,436,183	$8,848,690

Method 2

Mr. Finn(7) in his 1977 cost/benefit study assumed that improved sanitation would have a dual effect on the poultry industry, namely:

- reduce chick mortality by 0.25%;
- improve overall growth by 0.25% in terms of weight of finished broiler.

In total, more hygienic growing conditions would increase poultry production by 0.5%. Mr. Finn took into account the cost of feed, which was subtracted from the increased production value.

- Value of increased output:
  chickens: 511,785,000 kg x 0.005 x 1.1 $/kg = $2,814,818
  turkeys: 116,762,190 kg x 0.005 x 1.4 $/kg = $ 817,335
  $3,632,153
- Additional birds:
  number of additional chickens:
  1/1.7 (511,785,000) x 0.005 = $1,505,250

  number of additional turkeys:
  1/7.1 (116,762,190) x 0.005 = $ 82,267
- Cost of feeding additional poultry:
  chickens: 1,505,250 x 3.4 kg x $.251 /kg = $1,284,580
  turkeys: 82,267 x 20.7 kg x $.271 /kg = $ 461,493
  $1,746,073

  total value of increased poultry output:

  $3,632,153 - $1,746,073 = $1,886,080

Our Estimates

We have based our calculations on the second method, but we assume that the improved growth rate of 0.25 percent comes about without additional feed, in other words improved hygienic conditions have a beneficial effect on the feed conversion ratio. This means that only half of the additional feed would be needed at a total cost of $873,037. The total positive economic impact would therefore be:

$3,632,153 - $873,037 = $2,759,116

APPENDIX C

Measures that Can Be Taken to Improve Hygienic Conditions in Various Sectors of the Poultry Industry

1. To Produce Clean Hatching Eggs

- Maintaining clean nesting materials;

- minimizing the use of floor eggs. These eggs should not be packed or incubated with the remainder of the eggs, since they may contaminate the entire lot of eggs, chicks or poults in the incubator;

- avoid washing of hatching eggs;

- gathering eggs frequently, 4-5 times daily;

- storing out of the laying pen environment in a temperature controlled room;

- thoroughly cleaning and disinfecting all the building and equipment including waterers, feeders, feed bins, storage areas, and the building;

- controlling rodents, cats, dogs and birds plus a fly control program;

- using clean egg fillers and egg cases.

2. Maintenance of a Clean Hatchery Environment

- Accept only clean hatching eggs for setting;

- transport eggs in clean cases and trays, if trays are plastic, washed and disinfected after each use;

- clean and disinfect all egg handling equipment;

- supply all employees with clean clothing for hatchery wear and insist that employees' hands be washed with a germicidal soap several times daily;

- do not set eggs that have been laid on the floor. If it is essential to do so segregate them to one machine so as to avoid contaminating all lots in every machine;

- maintain a regular setter cleaning schedule;

- thoroughly clean and disinfect all equipment and hatchery surfaces after each hatch;

- Remove all dust from horizontal surfaces of the structure or equipment suspended from the ceilings or hanging on the walls;

- store supplies in a room away from dust and hatch debris;

- keep the doors to all rooms closed when not being used and screen all windows and doors as part of a fly control program;

- wash and disinfect all plastic chick boxes after each use. Monitor boxes to ensure that bacteria are being removed. Do not re-use cardboard chick boxes or pads;

- ensure that contaminated dust laden air is not being drawn into the hatchery from nearby poultry barns, processing plants or feed mills;

- ensure that exhausted air does not re-enter the ventilation system;

- eliminate old equipment that cannot be satisfactorily cleaned;

- repair floors with cracks that harbour dirt and micro-organisms;

- ensure that floors have adequate drainage. Do not allow water to lie on flat surfaces;

- clean duct work (inside) and fan and exhaust outlets regularly (also intake ducts);

- do not allow employees to move from poultry barns into the hatchery without changing clothing and footwear and/or showering;

- fumigate or wash and disinfect delivery vans at least twice weekly;

- change vaccine needles every few thousand chicks and thoroughly dismantle, clean and sterilize all vaccinating equipment each time used;

- clean and disinfect conveyor belts and chick sorting tables after each use;

- monitor surface cleanliness, apply disinfectants properly and know their efficiency, ensure employees know cleaning techniques; and collect fluff samples for laboratory analysis to determine the microbial load to the hatchery;

- maintain egg identity records throughout the hatchery, know all egg sources and flocks and link hatch results and laboratory analysis to flock situations so that a situation can be identified, corrected and/or removed from the operation;

- insist on specific conditions under which domestic and imported hatching eggs are to be produced.

3. Control Measures in the Grower Barns

- cleaning out, washing down and disinfecting all pieces of equipment and all areas of the building after each crop of birds;
- removing all equipment from the storage or entry of the building;
- spraying the ground within 30 feet of the entry with a 2% solution of formalin;
- not allowing dirty, unclean, undisinfected crates in the poultry barn;
- keeping people traffic to a minimum;
- insisting on pelleted or crumbled feed that has been treated to 175°F or 80°-85°C to kill all *Salmonella* present;

4. Clean Transportation Crates

Disinfectant efficacy is often poor due to:

- too low a concentration of disinfectant;
- disinfectant tied up in organic matter;
- poor application of disinfectant spray;
- disinfectant applied to recycled wash water rather than final rinse;
- nozzles poorly directed (insufficient number);
- water pressure too low;
- disinfectant not effective under the conditions used.

A problem which can only be overcome by redesigning the crate washer/bird unloading area, is that:

- washing is done in the unloading area;
- crates become recontaminated by dust and feathers;

- trucks are not always washed adequately before reloading the crates;
- no wall separates the washing area from the unloading area;
- ventilation systems set up air currents in the wrong direction;
- no second truck is available to handle washed crates.

5. Better Hygienic Conditions in the Processing Plant

- the processing plants must continue the daily clean-up and disinfection of all plant surfaces and equipment;
- plant employees must be made aware of the importance of following specific procedures to the production of quality product;
- plants must be monitored microbiologically;
- cleaning crews should be monitored micro-biologically and visually to determine their cleaning efficiency. Training should be provided;
- rinse nozzles must be maintained in operation, properly directed and operated at proper water pressure to clean effectively;
- special attention must be given to ensuring that feed is withdrawn from poultry 6-8 hours before loading to reduce fecal contamination of carcasses.

6. Hygienic Measures in the Feed Industry

- complete separation between raw and finished product areas;
- control of the movement of people between the raw and finished product areas;
- separate mobile equipment for each of the major areas - raw and finished;
- separate ventilation system for each area;
- fly, rodent and bird control;
- closure of all open ducts;
- cleaning and sanitation procedures known to be effective;
- all spillage of products on floors to be reprocessed;
- products to be loaded in clean trucks only;

- only new bags used for bagged product;
- plant equipment decontaminated periodically (dismantled and flushed with propionic acid, etc.);
- plants monitored environmentally to identify sources of contamination that may exist in the plant.

The feed mills who mix prepared feeds also have a major role to play by ensuring that:

- a bird, insect and rodent control system is in place;
- feed trucks are periodically cleaned inside and outside;
- truck operators are instructed on the hazards of entering poultry barns and moving from one farm to another;
- dust and debris are cleaned up in the mill;
- feed storage areas -silo, bins, are cleaned periodically;
- employees are instructed on plant sanitation;
- products with a minimum of Salmonella contamination are purchased from reputable suppliers;
- feed receiving area are maintained free from feed spillages;
- plants are monitored for Salmonella and if found, decontaminating the feed mill;
- pelleted feeds are held in bins for pelleted feeds only to avoid recontamination.

APPENDIX D

Some Financing Considerations

Financing Methods

Once we have acknowledged that a control measure would be a viable option in reducing Salmonella contamination in poultry, we must look at the financing aspect of it. There are two immediate options: the poultry industry pays or the government pays.

It could be argued that, as the control of salmonellae may provide general health benefits by reducing the risk of infection through cross-contamination, it should be financed by the government. After all, contamination of one food source may lead to infection not only in people who consume that food directly, but also to others who become infected through cross contamination of another medium.

a) The industry pays

If the industry has to pay for the implementation of the control measures, then the cost will be passed on to the consumers of poultry. However, it could be more expensive for the smaller producer/processor than for the larger one, and this could lead to increased financial pressure on the former, and increased concentration in the industry. Several questions arise. First, will the larger units be able to competitively fill the production gap in the region where the smaller producer/processor was eliminated? Second, elimination of smaller competitors would lead to increased concentration in the industry, thus strengthening oligopolistic powers which traditionally are believed to lead to higher prices. Third, if because of the elimination of a processor in a region, the producers of that region must transport their poultry to a more distant processor, thus incurring additional transportation costs, then, these producers could find themselves in a cost squeeze.

b) The government pays

Should the government subsidize the control measures, there would be a greatly reduced cost impact and less pressure to increase prices.

REFERENCES

(1) BARNUM, D.A., Department of Veterinary Microbiology and Immunology, Ontario Veterinary College, University of Guelph, Guelph, Ont. Salmonella Muenster: A New Problem in Ontario Dairy Herds. Highlights Vol. 6, No. 4 December, 1983.

(2) BLOOD, D.C., HENDERSON, J.A. and RADOSTITS, O.M., Veterinary Medicine. 5th edition, London: Ballière Tindall, 1979.

(3) BRYAN, FRANK L., Control of Foodborne Diseases. p. 265-269. IN The Safety of Foods. 2nd edition, 1980. Edited by Horace Graham. Avi Publishing Company, Inc., Westport, Ct.

(4) BRYAN, FRANK L., Current Trends in Foodborne Salmonellosis in the United States and Canada. Journal of Food Protection, Vol. 44, No. 5, p. 394-402 (May 1981).

(5) COHEN, DAVID R., The Benefit and Costs of a Ban on the Sale of Non-Pasteurised Milk in Scotland. Discussion paper 1982. University of Aberdeen.

(6) DAVIES, R.J., Education of Food Service Employees in: Food Poisoning and Its Significance in the Food-Service Industry. Health & Welfare workshop, 1976.

(7) FINN, PAUL J., A Benefit-Cost Analysis of Eradicating Salmonella Infection in Chicken Meat Produced in Canada. Agriculture Canada, May 1977.

(8) FRASER, FRANK M., Historical Overview and Potential of Food Irradiation. Atomic Energy of Canada Ltd.

(9) HASSAN, ZUHAIR and ROBBINS, LINDA, Handbook of Food Expenditures Prices and Consumptions. Agriculture Canada, 1983.

(10) HEALTH/AGRICULTURE/INDUSTRY COMMITTEE ON SALMONELLA, Report on the Scandinavian Salmonella Control Program in Poultry with Added Observations from Finland, Germany and Switzerland. November 1979.

(11) HEALTH PROTECTION BRANCH, *Food Borne Disease in Canada, Annual Summary 1978*. Health and Welfare Canada, Ottawa, 1984.

(12) KINGSTON, D.J. and SHAPCOTT, R.C., *The Reduction of Salmonella Sp. in and the Elimination of S. Typhimurium from a Commercial Broiler Breeding and Grow-Out Operation*. Presented before the section on Avian Medicine, 117th Annual AVMA Meeting, 1980.

(13) KRUG, WALTER and REHM, NORBERT, *Nutzen-Kosten-Analyse Der Salmonellose Bekampfung*. Schriftenreihe des Bundesministers für Jugend, Familie und Gesundheit, 1983.

(14) LANDEFELD, STEVE F. and EUGENE P. SEGUIN. *The Economic Value of Life : Linking Theory to Practice*. American Journal of Public Health. Vol. 72, No. 6 (June 1982) 555-566.

(15) LUCK, D., *Poultry Industry Profile*, Unpublished paper, Marketing and Economics Branch, Agriculture Canada, 1982.

(16) LEVY, B. AND W. McINTYRE, *The Economic Impact of a Food-Borne Salmonellosis Outbreak*. Jama, Dec. 2, 1974. Vol. 230, N° 9: 1281-1282.

(17) LITCHFIELD, JOHN H., *Salmonella Food Poisoning*. p. 120-175. IN The Safety of Foods, 2nd edition, 1980. Edited by Horace Graham. Avi Publishing Company, Inc., Westport, C.T.

(18) MINISTRY OF AGRICULTURE FISHERIES AND FOOD AND BRITISH VETERINARY ASSOCIATION, *Salmonellas in Poultry*. 1978. Report of a joint Ministry of Agriculture Fisheries and Food and British Veterinary Association Poultry Group.

(19) MORGAN, P.M., SADLER, W.W. and WOOD, R.M., *Food-Borne Diseases of Animal Origin*. In The safety of food, second edition 1980. Edited by Horace D. Graham. AVI publishing company, Westport, Connecticut.

(20) OOSTEROM, J. AND NOTERMANS S., *Verder Onderzoek Naar De Mogelijkheid Varkens Salmonella - Vrij Te Mesten En Te Slachten*. Tijdschrift Voor Dierengeneeskunde, Deel 108, 1983.

(21) OUWERKERK, THEO, Salmonella Control in Poultry Through the Use of Gamma Irradiation. Presented at the international symposium on combination processes in food irradiation. Sri-Lanka November 1980.

(22) PIVNICK, H. and NURMI, E., The Nurmi Concept and its Role in the Control of Salmonella in Poultry. Developments in Food Microbiology. Vol. 1, Appl. Sci., Publ. Ltd. London.

(23) RIGBY, C.E., J.R. PETIT, A.H. BENTLEY, J.L. SPENCER, M.O. SALOMONS AND H. LIOR, The Relationships of Salmonellae from Infected Broiler Flocks, Transport Crates or Processing Plants to Contamination of Eviscerated Carcasses. Canadian Journal of Comparative Medicine 46, July 1982.

(24) SALMONELLA COORDINATING UNIT, Salmonella in the Canadian Poultry Meat Industry. Agriculture Canada. 1981.

(25) SILLIKER, J., The Salmonella Problem: Current Status and Future Direction. Journal of Food Protection. Vol. 45, No. 7, May 1982.

(26) SIMARD, R.E. ET AUCLAIR, G., Cycle quotidien de contamination microbiologique des établissements d'abattage et de charcuterie "Approuvé Canada". Agriculture Canada Contract # OSW 76-00067-1977.

(27) STATISTICS CANADA, Cat. No. 13-206. Income Distribution by Size in Canada. Preliminary estimates 1978.

(28) STATISTICS CANADA, Cat. No. 71-001, monthly. The Labour Force. December 1978.

(29) STATISTICS CANADA, Cat. No. 82-206, Hospital Morbidity, 1978.

(30) STATISTICS CANADA, Cat. No. 23-202, Production of Poultry and Eggs, 1982.

(31) THIESSEN, G.P., The Efficacy of Chlorine Dioxide on Controlling Salmonellae Contamination and Its Effects on Product Quality of Chicken Broiler Carcasses. M. Sc. Thesis, University of Guelph, 1982.

(32) TODD, E.C.D., *Economic Loss Resulting from Microbial Contamination of Food*. Unpublished Paper. Bureau of Microbial Hazards. Health Protection Branch. Health and Welfare Canada.

(33) TODD, E.C.D., *Poultry-Associated Food-Borne Disease. Its Occurrence, Cost, Sources and Prevention*. Journal of Food Protection, Vol. 43, No. 2, Pages 129-139 (Feb. 1980).

(34) WEINER, HARRY, *The Origins of Salmonellosis*. Animal Health Institute, 1974 Washington D.C., U.S.A.

(35) WILLIAMS, J.E., *Paratyphoid Infections* p. 117-139 in Diseases of Poultry 7th ed. 1978, edited by M.S. HOFSTEAD, Iowa State University Press/Ames, Iowa.

LIST OF WORKING PAPERS PUBLISHED IN 1984

No. 1 Revision of the Forecasting Model for the Consumer Price Index for Food. A. Pierre Cloutier

No. 2 Plant Breeders' Rights: Some Economic Considerations - A Preliminary Report. Pamela Cooper. March 1984

No. 3 The Development of an Investment Planning Tool for the Meat Packing, Processing and Distribution Industry. Deloitte, Haskins & Sells, Associates. March 1984

No. 4E Structure and Economic Importance of the Canadian Food and Beverage Manufacturing Sector: Highlights of 1970 to 1981. Yvan Loubier. March 1984

No. 4F Importance économique et structure du secteur canadien des aliments et boissons: Les faits saillants de 1970 à 1981. Yvan Loubier. Mars 1984

No. 5 A Demand Matrix for Major Food Commodities in Canada. S.R. Johnson and A.N. Safyurtlu

No. 6 Economic, Nutritional and Physiological Evaluation of Feeding Food Processing Waste Products to Farm Livestock. P.G. Muller, W.J. Pigden, and W.W. Graham. June 1984.

No. 7 Freight Rate Adjustment Implications for Canada's Pork Trade with Japan. Keith A.J. Hay, and M.O. Lovatt. March 1984.

No. 8 Northeast Asian Market Potential for Canadian Foods to 1990 and 1995. Keith A.J. Hay, and Susanne R. Hill. March 1984.

No. 9 Potato Forecasting Model. Julien J. Destorel. July 1984.

No. 10 Economic Impact of Anaplasmosis in Canada. Ronald Krystynak. July 1984.

No. 11 Economic Study of Salmonella Poisoning and Control Measures in Canada. Leo Curtin. August 1984.

Available From:

André Trempe
Services Division
Marketing & Economics Branch
Sir John Carling Bldg.
Ottawa, Ontario
K1A 0C5

(613) 995-5880