POK AS A SOURCE OF HUMAN SALMONELLOSIS

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Salmonella can be transmitted from production animals to man either through direct contact at the farm or in the slaughter plant, or more frequently, by consumption of animal products. The magnitude of the risk of contracting salmonellosis by consumption of a given food product is influenced by several factors: qualitative and quantitative occurrence of salmonella, composition of the product (e.g. fat content), handling and preparation practices (e.g. cooking), susceptibility of the primary consumers (e.g. children foods), etc.

It is well established that a considerable risk of salmonellosis may be associated with the consumption of poultry or poultry products, especially eggs (Louis et al. 1988). Furthermore, in some countries beef and unpasteurised milk have been shown to be associated with sporadic occurrence of salmonellosis as well as outbreaks (Werner et al, 1984; Spika et al, 1987).

Salmonella in pigs and pork have less frequently been investigated from a public health perspective (Edel et al. 1976; Chau et al., 1977). In recent years pork has gained increasing attention as a source of human salmonellosis. In Denmark an increase in the incidence of sporadic human salmonellosis has been linked to increased occurrence of salmonella in pigs and pork (Baggesen & Wegener, 1994; Wegener et al. 1994). From United Kingdom an increasing occurrence of multidrug resistant Salmonella Typhimurium in pig production and spread to humans have been described (Threlfall et al., 1993; Wall et al., 1997; Ward & Threlfall, 1997) and finally, descriptions of major human disease outbreaks associated with pork (Maguire et al., 1993; Wegener & Baggesen, 1996; Molbak & Hald, 1997) has increased our awareness of pork as an important potential source of salmonella infections and has underlined the significance of applying means of controlling salmonella in pig and pork production.

It is the purpose of the present paper to illustrate that pork can be an important source of sporadic human salmonellosis, irrespective of a relatively low prevalence of salmonella in the products available for the consumer, and furthermore, a source of major disease outbreaks.

POK AS A SOURCE OF SPORADIC SALMONELLOSIS

Compared with the investigation of food borne disease outbreaks it is associated with an increasing uncertainty to determine sources of sporadic food borne infections. This is due to the fact that the amount of epidemiological evidence associated with each individual case is limited. Generally, two different sources of information are available: the information held by the bacterial isolate, and the information that can be obtained directly from the patient. Typing of bacterial isolates from patients may give indications about the source of the infection. If for example, the serovar isolated from a patient is frequently found in a given animal reservoir, but only rarely or never in other animal reservoirs, we may regard human infections with this serovar to be primarily associated with consumption of animal products originating from this reservoir. For instance, human infections with Salmonella Dublin would be assumed to originate from the

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bovine reservoir, either by consumption of beef or unpasteurised milk or through direct contact. Therefore, it would also be assumed that all relevant sources of infection are known. By application of bacterial typing methods such as phage typing, DNA fingerprinting a.o., we may further increase the predictive value of finding a specific type of salmonella in a patient with regard to pointing to a specific source for the infection. A general limitation to this approach is the fact that the sources of infections originating from food products cross contaminated during production from another type of product, may not be correctly determined. Therefore, this approach identifies the primary source of infections, in terms of the animal reservoir, rather than the actual food product implicated in causing the disease. In order to address questions about the specific commodities involved in the disease causation, information obtainable from the patient can be used. By interviewing groups of patients about consumption of specific foodstuffs or ways of handling food and comparing them to a group of matched control persons (a so called case-control study), elevated risks associated with consumption or handling of specific foodstuffs can be determined.

Sporadic salmonellosis in Denmark - incidence and sources of information: An increase in the incidence of food borne salmonellosis has been observed in Denmark over the last decade. In 1994 an incidence of 82.3 cases per 100,000 inhabitants was recorded. This is the highest number of cases ever recorded in Denmark. The two predominant serovars were S. Enteritidis with an incidence of 36.1 and S. Typhimurium with an incidence of 26.2 per 100,000 in 1994 (Figure 1). It is estimated that 80-90% of the cases are of domestic origin, and the majority of cases are of sporadic nature or belong to minor household outbreaks. One to two major outbreaks (>100
registered cases) have been recorded every year in Denmark since 1993.

![Bar chart showing salmonellosis in humans caused by salmonella sero-, phage, antibiogram-, and DNA types indicative of different production animals and foodstuffs.]

The impact of different animal products as sources of human salmonellosis in Denmark is estimated through a continuous comparison of salmonella isolates from humans to isolates from animals and foodstuffs by use of serotyping and epidemiological markers such as antibiogram typing, phage typing and DNA fingerprinting. During the period from 1984 to 1990 poultry, notably broilers, were the main source of human salmonellosis in Denmark. Three serotypes, namely S. Typhimurium, S. Enteritidis and S. Berta were the predominating serotypes in broilers as well as in humans during this period. A voluntary salmonella control programme established by the industry in the broiler production in 1988 was successful in reducing the occurrence of salmonella in broiler flocks from more than 70% in 1989 to 8% in 1996. At the same time the prevalence of salmonella in domestically produced broilers at retail was markedly reduced. Consequently the incidence of human salmonellosis caused by broilers has gone down (Figure 2). From 1991-1994 a new increase in the incidence of human salmonellosis was observed (Figure 1). This increase was associated with an increase in the occurrence of salmonella in pigs and pork. S. Typhimurium DT12 was the predominant sero- and phage type in pork as well as in humans during this period. In 1993 an outbreak of human salmonellosis caused by S. Infantis was traced to pork (see below). This outbreak, in combination with the high endemic level of pork-associated cases of sporadic salmonellosis in humans, made pork the most important source of salmonellosis in Denmark in 1993, accounting for approx. 20 cases per 100,000 inhabitants. The average level of salmonella contamination in fresh pork sampled in slaughterhouses during this period was approximately 3% compared to a level approximately ten times higher in broilers. Nevertheless, the number of human infections associated with broilers the same year was about 1/3 of that for pork. The reduction observed in human salmonellosis caused by S. Typhimurium from 1994 to 1995 was due to a simultaneous reduction in the prevalence of salmonella in pork (from 1.3% in 1994 to 0.8% in 1995). In 1996, an outbreak of salmonellosis caused by S. Typhimurium DT12 comprising more than 170 registered cases occurred (see below). This accounted for some of the increase in incidence observed in 1996 (Figure 1 & 2). In 1994 and
1995 the predominating serotype causing human salmonellosis was *S. Enteritidis*. The predominating phage types are phage types 1, 4, 6 and 8 with phage type 6 as the most important type. *S. Enteritidis* is only very rarely found in red and white meat in Denmark. Furthermore, all the phage types involved in human disease have also been found in layer flocks in Denmark. It is therefore assumed that eggs are the major cause of human infections with *S. Enteritidis*. This is supported by the observation that dishes involving raw eggs are the most frequent causes of outbreaks of human salmonellosis in Denmark in recent years. Based on the distribution of sero- and phage types in domestically produced and imported foodstuffs in Denmark and a comparison of this to the distribution of types involved in human disease, an estimate of the distribution of the sources of human salmonellosis in Denmark in the period from 1988 to 1996 has been produced (Figure 2).

**PORK AS SOURCE OF OUTBREAKS OF SALMONELLOSIS**

Since 1993 two major outbreaks of human salmonellosis in Denmark have been traced to pork. A combination of high salmonella infection rates in large supplier herds to pig slaughterhouses and temporary breakdown of hygiene procedures was the most likely explanation for these outbreaks. Furthermore, the relatively large extent of both outbreaks was explained by the fact that both slaughterhouses, despite a relatively small production, supplied to a large number of domestic consumers.

*Salmonella Infantis* outbreak in Denmark 1993: In the period April to August 1993 an outbreak of human salmonellosis involving more than 500 registered cases of infections with *S. Infantis* was recorded in Denmark. In comparison the total number of registered cases in 1992 was fortyone. The majority of infections were recorded on the island of Zealand. Investigations by the municipal food control laboratory showed that meat from the central meat market in Copenhagen was contaminated with *S. Infantis*. The central meat market supplies to butcher’s shops in Copenhagen. By sampling from trucks before unloading at the market it was determined that pork from one particular slaughterhouse was contaminated with *S. Infantis*. Investigations at the slaughterhouse subsequently showed high levels of *S. Infantis* at the production line and in the chillers. The slaughterhouse was closed down for cleaning and sanitation. Furthermore, slaughter pigs from a number of supplier pig herds which had been shown to be infected with *S. Infantis*, were diverted for slaughter in other slaughterhouses better capable of handling the infected animals hygienically. Following these actions the outbreak ended. During the outbreak, analysis of chromosomal DNA restriction patterns produced by pulsed field gel electrophoresis (PFGE) was used to investigate the bacterial isolates. All human isolates from the outbreak belonged to a single type - the "EPI-type", whereas human isolates recovered before and after the outbreak belonged to several different types. All isolates investigated from the slaughter plant associated with the outbreak and its supplier pig herds belonged to the EPI-type. Isolates from pork from the central meat market in Copenhagen, which had received most of the carcasses from the plant, also belonged to the EPI-type, as did isolates from beef from the same market, indicating that cross-contamination had taken place. All isolates from pork and some, but not all, isolates from beef, collected in butcher’s shops in Copenhagen during the outbreak belonged to the EPI-type. Isolates of *S. Infantis* from pork originating from other slaughter plants and isolates from poultry were shown to belong to several different PFGE types. The typing results supported that the outbreak
was a common source outbreak, probably originating from a limited number of supplier pig herds supplying animals to a single slaughterhouse. The results of the investigation furthermore suggested that cross-contamination to beef and other meat products occurred frequently during processing and handling of pork after it had left the slaughterhouse probably increasing the magnitude of the outbreak. The fact that the outbreak was caused by a rare serotype with a specific molecular subtype played a vital part in the rapid identification and solution of this outbreak.

*Salmonella Typhimurium outbreak in Funen county, Denmark, 1996*: The outbreak occurred in late summer 1996 and involved 170 registered cases, primarily in Funen county, Denmark. The outbreak was initially identified by an elevated level of *S. Typhimurium* DT12 infections in the county. A municipal food control laboratory identified a local slaughterhouse as a possible source of the outbreak by culture of *S. Typhimurium* DT12 from products originating from this slaughterhouse. Extensive sampling at the slaughterhouse only produced a single sample positive for *S. Typhimurium* DT12. This salmonella type predominated among isolates from pork and beef in DK at the time. Furthermore PFGE typing did not identify characteristics particular to the outbreak isolates. Therefore, the finding could not in itself be regarded as sufficient proof of the association. Thus, a matched case-control study was initiated. Altogether, 47 cases and 89 controls were interviewed about purchase, consumption and handling of food as well as other factors considered to be of relevance. No single food item could be associated with *S. Typhimurium* infection. However, when including the origin of the pork consumed in the analysis the results showed that consumption of pork from the slaughterhouse concerned was strongly associated with *S. Typhimurium* DT12 infection.

**DISCUSSION**

The examples presented here show that pork is a source for sporadic human salmonellosis as well as outbreaks of salmonellosis. In Denmark, relatively high levels of sporadic salmonellosis has been associated with the consumption of pork at times where the level of salmonella in fresh meat at retail lay in the range from 2-3%. An important observation in this respect is that, even though the levels of salmonella in slaughter chickens at retail where 5-10 times higher, they were estimated to cause fewer cases of infection during the same period. Thus, levels of salmonella in foodstuffs have to be evaluated cautiously when estimating the risk associated with consumption of pork products.

**REFERENCES**


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