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A qualitative risk assessment for human salmonellosis due to the consumption of fresh pork in Belgium

Een kwalitatieve risicoanalyse voor humane salmonellose veroorzaakt door consumptie van vers varkensvlees in België

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ABSTRACT

Although pigs contaminated with *Salmonella* rarely show clinical symptoms, control is important because of the public health concern. Both producers and consumers are interested in procedures for minimizing the risk of *Salmonella* infections. This study outlines the entire production path for fresh pork in Belgium, from farm to fork. Additionally, it describes the different critical points for *Salmonella* contamination, with emphasis on those steps that need extra attention and/or improvement. The data was collected by means of questionnaires at the different steps of the process. In total, 3658 questionnaires were collected, which made it possible to draw up a nationwide image of the pork production process.

In the primary production phase, there are several points relating to biosecurity that can be improved in order to minimize the risk for *Salmonella* in fattening pigs that are sent to slaughter. In the slaughterhouse, there has been an increase in the number of pigs or carcasses that become infected with *Salmonella*. Attention should be paid to avoiding contact of the feces and tonsils of contaminated pigs with the carcass, and strict hygienic measures should be taken to avoid cross-contamination.

During the transformation and distribution of the carcasses, there is a low risk of further spreading of *Salmonella spp*. Finally, during the consumer phase, the risk for *Salmonella* contamination increases because of inappropriate temperature conditions during storage, manipulation of the meat and possible cross-contamination with other food products, and the consumption of insufficiently heated and/or raw meat.

The present study illustrates that the risk of *Salmonella* infection by consumption of fresh pork is relatively low under Belgian conditions. Nevertheless, it can be further decreased by implementing additional control measures, mainly in the slaughterhouse and in the domestic kitchen.

SAMENVATTING

Hoewel varkens die besmet zijn met *Salmonella*, zelden klinische symptomen vertonen, is *Salmonella* controle belangrijk voor de volksgezondheid. Zowel producenten als consumenten zijn geïnteresseerd in procedures die het risico op een *Salmonella* besmetting kunnen minimaliseren. In deze studie wordt het hele productiepad van vers varkensvlees van riek tot vork beschreven, met extra nadruk op de kritische controlepunten. Gegevens over de verschillende stadia van het productiepad werden verzameld door middel van 3658 enquêtes zodat een globaal beeld kan gegeven worden van de Belgische productie.

In de primaire productiefase zijn er verschillende punten die voor verbetering vatbaar zijn en het risico op *Salmonella* besmetting zouden kunnen minimaliseren. In het slachthuis is er een stijging van het aantal varkens of karkassen besmet met *Salmonella*. Het contact tussen feces en tonsillen enerzijds en karkassen anderzijds zou vermeden moeten worden en strikte hygiënemaatregelen dienen genomen te worden om kruiscontaminatie te vermijden. In de uitsnijderij en de distributie is er een laag risico op een verdere spreiding van *Salmonella*. Tijdens de consumentenfase is er een hoger risico op *Salmonella* besmetting omwille van een vaak te hoge bewaartemperatuur, de mogelijke kruiscontaminatie met andere voedingsmiddelen en het consumeren van onvoldoende gebakken of zelfs rauw vlees. In deze studie wordt aangetoond dat het risico op *Salmonella* besmetting in België door de consumptie van vers varkensvlees relatief laag is. Desalniettemin kan het risico verder verlaagd worden door bijkomende controlemaatregelen te nemen, voornamelijk in het slachthuis en in de keuken.

INTRODUCTION

Salmonella is one of the most important causes of food-borne illnesses in humans (Van Loock *et al.,* 2000*)*. In 2006, there were 3693 reported cases of *Salmonella* in Belgium (NRCSS, 2006). Since 2004 there has been a significant decrease of *Salmonella* infections in Belgium and in the whole of Europe (Community Summary Report on zoonoses, 2006). The reported incidence, however, is likely an underestimation of the actual incidence because not every person with clinical symptoms consults a medical doctor, and even for those who do, stool samples are not always taken for analysis of *Salmonella* (Van Loock *et al*., 2000).

The most common causes of *Salmonella* infection in humans are, in order of decreasing importance, the consumption of fresh meat, of processed meat products (poultry and pork), of eggs and of egg products. Hald *et al*. (2004) showed that 9% of the food-borne *Salmonella* cases in Denmark could be attributed to the consumption of pork. In Belgium, *Salmonella* Typhimurium (most common serotype in pork) represents 49.6% of all strains from human cases typed by the NRCSS (2006). In developed countries, there is constant public concern about the microbiological safety of food (EFSA, 2006; Nollet *et al*., 2005). Producers, consumers and the relevant authorities are all interested in implementing procedures to mitigate the risk of *Salmonella* (Alban *et al.,* 2005). In the present study, we will focus on pork as a source of *Salmonella* infection. The microbiological safety of pork depends on many factors such as hygiene and infection level in pig herds (Nollet *et al*., 2005)*,* hygiene during carcass processing in the slaughterhouses (Borch *et al*., 1996)*,* the storage and distribution conditions of the carcasses and, finally, the handling of pork by the consumer (Hill *et al*., 2003).

Previous risk assessment studies (Berends *et al*., 1997; Swanenburg *et al*., 2001) focused mainly on specific parts of the production process such as the primary phases of production, the slaughterhouse and the retail phase. Risk assessment studies dealing with the entire production chain are scarce (Hill *et al*., 2003).

Performing a qualitative risk assessment study is a first and necessary step towards performing quantitative microbiological risk assessment (QMRA). For the qualitative approach, a systematic overview of the production processes of fresh pork meat with the consequential risks involved is necessary. For this purpose, two types of information are needed. First, the production process needs to be described in detail. Second, all relevant risk factors need to be identified and the frequency of occurrence needs to be estimated. As for the second type, large amounts of information are available in the literature, whereas for the first type, very little data is available and the circumstances may differ greatly between countries.

The aim of this study was to investigate the production of pork meat from farm to fork in Belgium, to identify critical points along the production chain, and to make a qualitative microbial risk assessment for *Salmonella* in pork meat. Since approximately 50% of the meat from Belgian slaughter pigs is exported, a risk assessment study for the Belgian situation is also important for many other countries.

MATERIALS AND METHODS

Development of the model

This risk assessment model was developed following the methodology described by the Codex Alimentarius of the WHO for microbiological food safety risk assessment. This risk assessment consists of four steps: (1) Hazard Identification, to identify the pathogen that is causing the disease; (2) Hazard Characterization, to evaluate the nature of the pathogen, and estimate the dose response; (3) Exposure Assessment, to describe the biological pathway(s) necessary for the exposure of animals and humans, and to estimate the likelihood of this exposure occurring; (4) Risk Characterization, which consists of integrating the results from the hazard characterization and the exposure assessment to develop an estimate of the probability of occurrence and severity of the disease in a given population.

Data collection

Every step of the production chain, from the birth of the piglets till the consumption of the meat, has been considered in the process.

The whole process was divided into four different phases: 1) primary production, 2) transport and slaughterhouse, 3) transformation and distribution and 4) consumption. These four phases were further subdivided into different steps. The possible influence of each step of the production chain on the occurrence of *Salmonella* was investigated. To be able to construct a risk assessment model that corresponds well to the Belgian situation, data concerning every step of the production process was collected.

Primary production phase

Between May and August 2005, written questionnaires were sent by conventional mail to 609 Belgian pig herds. The sample frame consisted of pig herds that were randomly selected from the official national Identification and Registration (I&R) pig database (Sanitel, 2005). Prior to sampling, selection of the herds was done by stratifying per province (10 provinces). At least one pig had to be present at a geographical location, based on a recent visit of the herd veterinarian (after September 2004). One month after the first letter, a reminder letter was sent again by conventional mail. Besides questions concerning biosecurity and contact structure (Ribbens *et al*., 2008a; Ribbens *et al*., 2008b), 54 questions were added to the questionnaire concerning different known risk factors for *Salmonella* and hygiene measures. The questions were semi-open or closed. From the 609 questionnaires sent, we received 436 responses, which meant a response rate of 71.6%. Of these 436, there were 300 herds that fully completed the questionnaire and had at least 100 fattening pigs. Because we intended to include only professional pig farmers, only these 300 questionnaires were used in the study.

Slaughterhouse phase

The slaughter process was investigated in the 10 largest Belgian pig slaughterhouses (in terms of number of slaughtered pigs per year) by means of a visit by the principal investigator and a questionnaire. In these 10 slaughterhouses, 6.66 million pigs in total are slaughtered (627,972 tons of pork carcasses) annually, corresponding to 60% of the total Belgian pig slaughter capacity. In each slaughterhouse, data related to the production path and the process was obtained by visual inspection of the slaughter line, by taking measurements at several stages in the slaughter process, and by interviewing the manager responsible for the quality assurance of the slaughterhouse. The questionnaire included 90 questions pertaining to the cleaning and disinfecting procedures, the products used for cleaning and disinfection, manufacturing data, training of the personnel concerning the hygiene protocol, and functioning of the equipment and machines. The questionnaire used was pilot tested in one slaughterhouse. All interviews were completed by the same researcher. In addition to the information obtained from the questionnaire, the temperatures of the scalding water, of the water used for dehairing and polishing, and of the water used for cleaning knives for evisceration were measured. The pass-through times in most of the machines were also measured.

Transformation and distribution phase

Eleven cutting plants for pork meat in Belgium were selected based on their meat processing capacity in 2004. The amount of meat processed by the 11 cutting plants represented 10.5% of the total capacity of pork meat processed in Belgium. The eleven cutting plants were visited between September and November 2005. During each visit, the quality manager was interviewed and a questionnaire was filled in. The questionnaire included 57 questions pertaining to the cleaning and disinfecting procedures, the time-temperature schedules, vermin control, and the hygiene procedures for the workers. The questionnaire was pilot tested in one cutting plant. The temperature of the meat was measured at different stages in the cutting process. The temperature of the working area and of the fridges was measured as well.

Consumer phase

A national health interview survey involving 3028 participants was performed in 2004. The survey was conducted using face-to-face interviews and a structured questionnaire. The sampling frame contained people representing a cross-section of the population aged 15 and above. They were stratified by age, socio-economic situation and geographical sector based on the national register. Persons that refused to participate were replaced by someone with the same characteristics (matched individuals). The people were classified into four age groups: from 15 to 18 years, from 19 to 59 years, from 60 to 74 years, and 75 and older. The questions concerned socio-demographic characteristics, lifestyle, consumption of food during the previous 24 hours, and consumer habits relating to meat purchase, preservation and preparation.

Additional information

Besides the on-site collection of information on the production process, all relevant information concerning the production of pork and the occurrence of Salmonellosis was collected in the scientific literature and from the available datasets of official and private organizations. During the screening, we focused as much as possible on the production path of fresh pork meat and the prevalence of *Salmonella* in humans. Mainly information on *Salmonella* Typhimurium was gathered, but information related to contamination by other food toxic infections that may be relevant for our study was also collected.

The dataset used for determining the herd prevalence of *Salmonella* and the carcass prevalence in the slaughterhouses originated from the security program of the Federal Food Agency. The Community Summary Report on zoonoses (2005) was used for the data concerning human cases of *Salmonella* in the EU. The information used to estimate the incidence of *Salmonella* infections in Belgium originated from the NRCSS 1962 – 2005, the national reference lab for food-borne diseases, the surveillance by a network of laboratories, the research project on food-borne diseases by a sentinel network of general practitioners and the data from the institute for illness and health insurance (RIZIV).

RESULTS AND DISCUSSION

Hazard identification

Salmonella spp. are zoonotic Gram-negative bacteria belonging to the Enterobacteriaceae. Until 2004, *Salmonella* was certainly the main cause of infectious food-borne diseases in Belgium, with about 10,000 cases per year. The most frequently isolated serovars in Belgium in 2005 were *Salmonella* Enteritidis (45%) and *Salmonella* Typhimurium (34%) (NRCSS, 2005). This last serovar is mostly associated with pigs and pork meat. Each year, a seasonal peak of *Salmonella* infections is observed during the period of July to September. This is probably due to the BBQ season with the consumption of more insufficiently heated meat and cross-contaminated salads. The serovar repartition by age groups indicates that *S*. Typhimurium occurs more often in patients younger than 5 years. However, the interpretation of the age group repartition of *Salmonella* cases is difficult because it is not possible to exclude the influence of some medical practice habits such as the more frequent examination of stool samples of young children.

Hazard characterization

Salmonella can multiply in food products if the temperature during storage and transportation ranges from 5 to 46°C, with optimal growth at approximately 37°C (Ekperigin et Nagaraja, 1998). In principle, *Salmonella* is destroyed when the temperature exceeds 70°C. However, the effectiveness of heat treatment depends on the humidity of the product: in some cases where *Salmonella* was inoculated in poultry feed samples (100 cells/g), and where the oven reached a maximum temperature of 186° C and had a final moisture content as low as 0.8%, about 25% of the samples remained positive after treatment, whereas in flowing steam, with a maximum feed temperature of 90° C and a final moisture level of 15%, after 1, 5, 10, and 20 min of flowing steam, 100, 90, 60, and 0% of the samples, respectively, were found to contain *Salmonella* (Burdick *et al*., 1983). When *Salmonella* is surrounded with organic matter, it can survive for a longer period in the environment and resist chemical disinfection. The pH range in which growth of *Salmonella* is possible extends from 4.0 to 9.5 (Ekperigin *et al.,* 1998). Pigs infected with *Salmonella* Typhimurium in general do not show any clinical symptoms (Côté *et al*., 2004). The symptoms associated with *Salmonella* infection in humans include acute fever and diarrhea varying from acute watery diarrhea to bloody diarrhea or dysentery. In most cases, the infection is self-limiting. In YOPI's (= young, older, pregnant and immunodeficient patients), *Salmonella* can cause bacteremia, meningitis septic arthritis, osteomyelitis, cholangitis, pneumonia and occasionally death (Hohmann *et al*., 2001). The program "Standardized Procedures for Mortality Analysis", which is available on the website of the National Institute of Public Health (IPH, www.iph.fgov.be/epidemio/spma/), indicates a total of 21 deaths directly attributed to *Salmonella* infections in 1997 in Belgium. *Salmonella* infections in humans can also result in asymptomatic carriership, as well as reactive arthritis.

Exposure assessment

The production path has been described in detail, taking into account all possible influential steps for *Salmonella* contamination.

Primary production

In 78% of the Belgian pig herds, nose-to-nose contact is possible between pigs in neighboring pens. Given the fact that pigs become infected with *Salmonella* mostly by oral-fecal transmission (Schwartz *et al*., 1999), this easy contact between pigs in different pens provides an efficient route of *Salmonella* spread through the herd. Lo Fo Wong (2004) demonstrated that herds in which snout contact between pigs in neighboring pens was possible had 1.7 times higher odds of testing seropositive compared to pigs for which such contact was not possible. The frequent moving of pigs between pens and compartments (in 54% of the Belgian herds, pigs are moved to another compartment at least once during the fattening phase) may also result in the spreading of *Salmonella* spp. The moving of animals may also result in increased stress, which has been shown to be an inducing factor for *Salmonella* shedding (Berends *et al*., 1996; Isaacson *et al*., 1999; Nollet *et al*., 2004). Animals entering the stables are also potential contributors to *Salmonella* spreading within the pig herd itself. Because cats and dogs can passively carry *Salmonella* spp. on their coat and can also be active shedders of *Salmonella* (Evans *et al*., 1996), they should be kept out the stables as much as possible. Nevertheless, the results of our study indicate that only in 22% of the surveyed herds do cats or dogs never enter the stables. Rodents, insects and birds have also been described as potential carriers or spreaders of *Salmonella* (Meerburg *et al*., 2006). In Belgian fattening pig herds, 93% have a rodent control program and 71% take measures against insects. On the other hand, 47% report that birds can easily enter the stables. The results thus indicate that rodent and insect control is generally well applied, but improvement is needed in keeping birds out of the herds. Apart from animals, the farmer or visitors may also be responsible for introducing and/or spreading *Salmonella* within the herd. On 80% of the herds interviewed, visitors have to wear special clothing available on the premises of the herd itself, and 77% of the farmers always wear this clothing themselves. This special clothing should be washed or changed frequently to prevent the spreading of disease agents by the farmer when he is working around the pigs. Only 41% of the farmers claim they have a disinfection bath at the entrance location. To prevent disease spreading within the herd, 56% claim they (sometimes) use disinfection baths between different compartments or between different barns.

As for evaluating the risk of disease introduction through equipment, it seems that only 6% of the respondents use equipment from other herds. Of the minority (6%) of the Belgian herds that use machines from other herds, 22% report not using any preventive measures (cleaning, disinfection) to counter this risk factor. More important is the fact that nearly 52% of the Belgian herds use the same equipment (shovel, broom, etc.) in different rooms or barns, which may promote internal spreading.

Van Winsen *et al*. (2005) showed under experimental circumstances that the combination of organic acids and low pH of feed and/or drinking water have a strong negative influence on the survival and/or multiplication of *Salmonella* in the gut of pigs. Of all the respondents, only 7% acidified the drinking water, 4% the feed and 1% both. Currently, more and more herds are using acidified core meal in the feed (personal communication, Belgian Mix and Feed Companies). In this area, there is certainly room for improvement.

Transport and slaughterhouse phase

When pigs leave the farm, they can be exposed at several points to the risk of *Salmonella* infection. It has been shown that the proportion of pigs shedding *Salmonella* significantly increases between the farm and the slaughterhouse (Hurd *et al*., 2001). This group of shedding pigs consists of pigs with reactivated infections, pigs that were already excreting *Salmonella* before transport, and pigs infected by other pigs in the same shipment (Berends *et al*., 1996). The risk for the development of new infections is of course dependent upon the duration of transport. Hurd *et al*. (2001) indicated that a transport time of as little as half an hour can be enough to lead to infection. In Belgium, transport to the slaughterhouse takes on average 74 minutes (min 23 - max 137). In 96% of the cases, the pigs are taken to the slaughterhouse by a transport firm. The number of pigs on a truck is on average 100, (with a range of from 2 to 240). Slaughter pigs are kept in lairage on average 126 minutes (min 5 - max 720). Pigs of different herds are not placed together in the same pen in the lairage, but the pens are not cleaned before new pigs from a different herd are brought into these pens. Consequently, it is possible that pigs become infected with different serovars of *Salmonella* during the waiting period in the lairage. According to Hurd *et al*. (2002), Swanenburg *et al*. (2001) and Beloeil *et al*. (2004), the lairage is a possible risk factor for infection of pigs. Eighty percent of the interviewed slaughterhouses clean the lairage area daily and 10% clean it on a weekly basis, while 10% answered that they never clean the lairage area. More remarkable is the fact that three out of ten slaughterhouses never disinfect the lairage.

After the lairage, the pigs are stunned, bled and subsequently scalded. A time-temperature combination of 1.4 min at 60°C is required to achieve a 1 log reduction in *Salmonella* in scald tank water (Bolton *et al*., 2003). This was achieved in all the slaughterhouses (average 6.7 min at a temperature of on average 60.5°C, with a minimum of 58.5°C measured and a maximum of 63.7°C). Subsequently, the scalded carcasses are dehaired, mostly using cold water. During this step in the process, fecal material can be spread all over the carcass surface. In addition, the dehairing machine is very difficult to clean properly, which makes this step a very critical hazard point (Bolton *et al*., 2002). Pearce *et al*. (2004) observed an increase in *Salmonella* positive carcasses of from 1 to 7% due to the dehairing process. In the next step, the carcasses move through a flaming device for a period of 5 to 16 seconds. Bolton *et al*. (2002) could not detect any *Salmonella* on the carcasses after this stage. Pearce *et al* (2004) showed that the singeing process strongly reduced the number of *Salmonella* contaminated carcasses, namely from 7% to 0%.

In the polishing step, the carcasses can be re-contaminated due to feces which can be 'wringed out' during this step (Borch *et al*., 1996). In addition, this equipment is difficult to clean and disinfect, and bacteria may establish on the surface of the brushes and scrapes, thus resulting in an efficient cross-contamination (Borch *et al*., 1996). Polishing equipment contributes to an estimated 5-15% of total carcass contamination with *Salmonella* spp. (Berends *et al*., 1996). Two of the slaughterhouses visited had an additional flaming step after the polishing. This is an effective and efficient way of reducing the contamination of the carcass that may have occurred during polishing.

In the clean part of the slaughter process, the rectum is first circumcised either manually (20%), or else mechanically with a bung cutter (80%). During the subsequent procedures, *Salmonella* bacteria may spread to the carcass from the intestines, the stomach content, the oral cavity, or the esophagus, and also from the lungs in the case of vat scalding. In 2 out of the 10 slaughterhouses, a steam tunnel is used instead of vat scalding, and with such a steam tunnel it is less common that dirty water fills the lungs. According to Berends *et al*. (1997), evisceration practices contribute to an estimated 55-90% of total carcass contamination with *Salmonella* spp. In the slaughterhouses visited, the temperature of the water used for cleaning the evisceration knives and the bung cutter varied from 47°C to 81°C, whereas this should be at least 82°C (Regulation 853/2004). The knives were not cleaned between every carcass, but were held for one second in the hot water every third or fourth carcass. In the worst case situation, this was done only when the intestines were accidentally opened. The limited cleaning frequency for the knives is probably due to the high and intensive slaughtering speed in the Belgian slaughterhouses (between 285 to 550 pigs per hour). During evisceration, the intestines can get accidentally opened, resulting in the spreading of fecal material over the carcass. This risk can be reduced by fasting of the pigs before slaughter. In 97% of the herds responding, the slaughter pigs are fasted on average for 17 hours, which likely results in a great reduction of the risk.

According to a study by Bolton *et al.* (2002), the washing of carcasses with cold potable water after evisceration did not have any perceivable decontamination effects. Rather than achieving net reductions in bacterial numbers, final washing increased the bacterial counts between 3.6 and 3.8 log cfu per cm^2. If a decontamination effect is desired, wash water with a temperature of 85° C or higher is necessary (Gill and Penney, 1979; Alban *et al*., 2005). Nevertheless, 8 out of the 10 slaughterhouses did wash the carcass with cold water if visible contamination was present.

In the next step of the slaughtering process, the carcasses are split automatically with one or two splitting machines. During the splitting process there is a potential risk that the device will come into contact with the rectum and/or the tonsils, which may result in contamination. When this machine is not properly cleaned and disinfected between two carcasses, there is again a possibility for cross-contamination. The first and second machines were cleaned and disinfected in 70% and 30% of the cases, respectively. After splitting, the carcasses are inspected, weighed, graded and chilled. The inspection is again a critical point because of the manipulation of the tonsils and the carcass. Pathogenic bacteria from the tonsil region can contaminate other parts of the carcass through manipulation by the knives and hands of the meat inspection personnel (Nesbakken, 1988) (Figure 1).

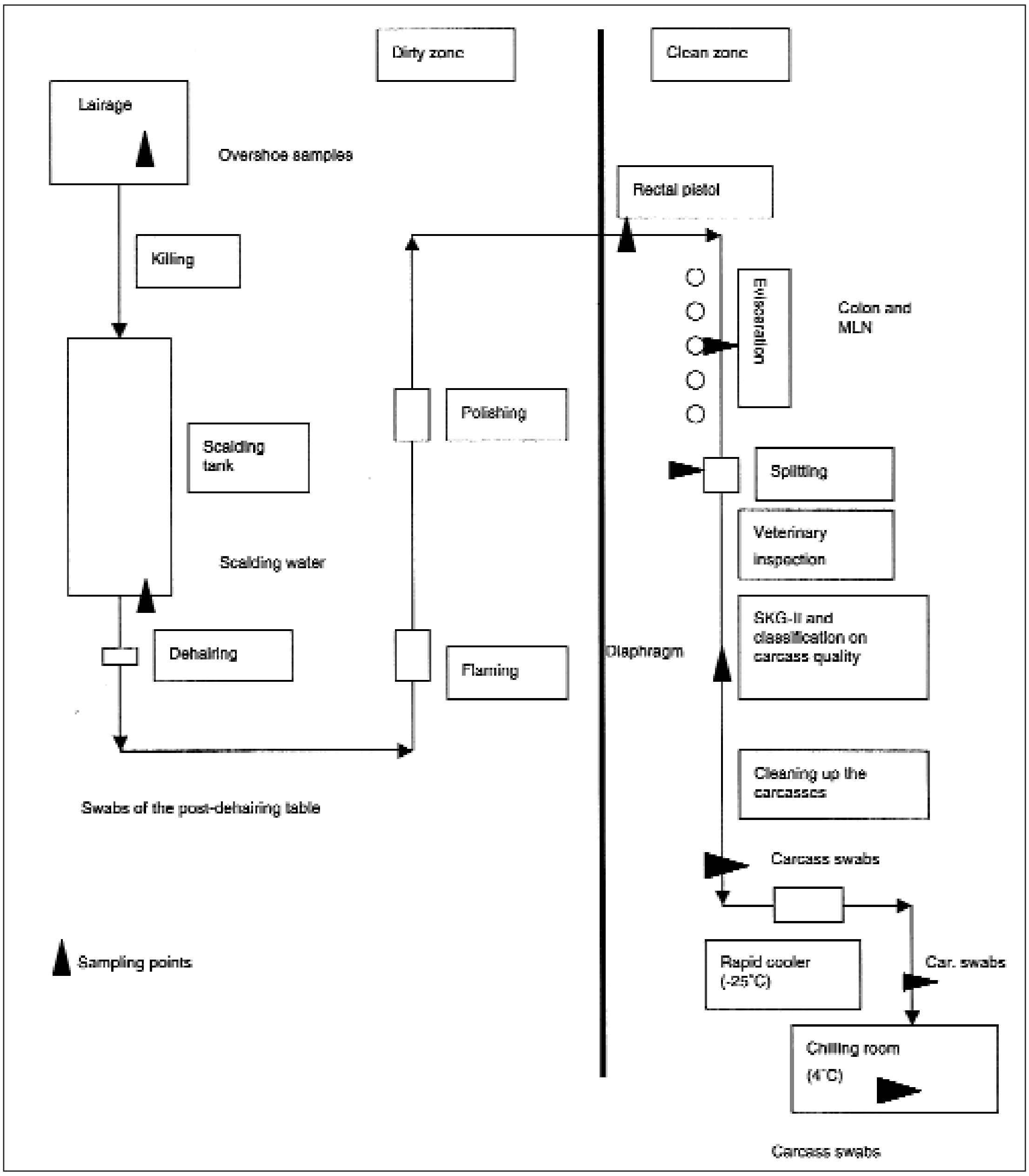

Figure 1. Slaughterhouse production path (adapted from Botteldoorn *et al*., 2003).

Transformation and distribution

The cutting plant phase is very complex due to the huge variability in production characteristics between different cutting plants. In the slaughterhouses, the carcasses must leave the chilling room with an internal temperature below 7° C (Anonymous, 2006). Sometimes no transport is necessary since the cutting plants are located next to the slaughterhouses. In all other cases, the carcasses are transported to the cutting plants using a refrigerated truck. The half carcasses are first cut into the usual sections, such as shoulder, back, ham and belly, and then further into smaller pieces. Then the pieces of meat are conditioned, stored in a cold room and transported with a refrigerated truck to the stores and butcher shops. In these stores, the pieces of meat are either placed directly in the fridges for the customers or are further divided into smaller portions.

According to Berends *et al*. (1998), the major risks during processing in the cutting plants are inadequate cleaning and disinfection, cross-contamination of the meat due to direct contact, and the manipulation of the meat with contaminated materials or on contaminated surfaces. The number of manipulations is difficult to count, depending mainly on the type of final meat product. For cleaning and disinfection of the knives, washing machines are used. This is generally done during the lunch breaks and at the end of the day. The cutting and mincing machines, the tools, the conveyor belts and the surfaces of the cutting plates are washed and disinfected once at the end of the day. The refrigerators are washed and disinfected only once a week. None of the companies visited have sterilizers for disinfection of the knives during the day, but the butchers can clean them in hot water vats. The stainless steel holding vats are washed once at the end of the day. Insect and vermin control are in all cases outsourced to an external company. The critical hazard point in the cutting plant phase is the working area, where the temperature is between 8 and 12° C. The meat remains in the working area on average for 38 minutes (min. 5 – max. 150). Other places, such as the chilling rooms and during transport, were less critical since the temperature was always less than 4° C.

The meat is usually cut and distributed within 24 hours after slaughter, though the interval can be longer when the slaughtering takes place just before the weekend or holidays. Subsequently, small pieces of meat are transported to the distribution stores, where the meat can be prepared for the consumer as cutlets, minced meat, etc.

Consumer phase

In Belgium, people consume on average 9.7 kg of pure fresh pork meat per year. In addition, the consumption of mixed fresh meat is about 11.6 kilo. This mixed meat mostly contains pork (Gfk panel services Benelux). As a result of different consumption habits, there is a large variation in the amount of meat consumed by different persons. In Belgium, only 56.3% of people (95% CI 53.7-58.8) consume meat or meat products daily, and the females in any age group consume less meat than the males.

The risk at the consumer level can be expressed at three levels: purchase and transport to home, storage at home, and preparation and consumption. At each level, the risk can be linked either to consumer behavior or to external factors. In general, Belgian consumers do not use a cooling box in their cars. At home, they store the meat at 7° C (varying from 6.2° C – 7.2° C). Eighty-five percent of the consumers are aware of the fact that it is a risk to use the same plate for cutting the vegetables after having cut the meat. There was no question included as to whether the meat and vegetables are kept separated. Seventeen percent of the persons consume raw meat more than once a week (males 20.8%; females 12.9%). A difference according to age was also noted: older people consume less raw meat, though it is not known whether this is also the case specifically for pork meat.

Risk characterization

Primary production

If *Salmonella* enters a pig herd, efficient transmission of the disease is possible in most cases. This is due to the intensive contacts between pigs of different pens in almost all herds. Additionally, pigs are frequently moved between pens, which also enhances the spreading of the disease. Some internal biosecurity measures can be taken to minimize this spreading within the herd, such as preventing nose-to-nose contact, changing the feed composition (Van Winsen *et al*., 2005), acidification of the drinking water (Van der Wolf *et al*., 2001c), and hygiene and husbandry (Jensen *et al*., 2006). Other measures include restricting the access of dogs, cats and birds to the pig area and avoiding the use of the same equipment in different rooms. In general, it can be concluded that if *Salmonella* enters a fattening pig herd, the bacteria can spread rather easily. This is also confirmed by the results of the *Salmonella* monitoring program, which found that the overall within-herd prevalence in Belgium is 36.80% (CI: 36.29-37.32).

The slaughterhouse

Within the entire process of whole pork meat production, the slaughterhouse has been identified as the most important source of *Salmonella* contamination of the carcasses (Hurd *et al*., 2002; Botteldoorn *et al*., 2003). It is estimated that about 70% of all carcass contaminations result from infected (carrier) animals, and 30% are due to cross-contamination (Berends *et al*., 1997; Botteldoorn *et al*., 2003).

The greatest risk in an average slaughterhouse in Belgium occurs when the carcasses are polished and eviscerated. To reduce the risk caused by polishing, slaughterhouses may add a second flamer after the polishing. Since only 2 out of of the 10 slaughterhouses visited have a second flamer, there is still room for improvement. The risk of contamination of the carcass during evisceration is more difficult to control. Nevertheless, some improvements such as increasing the temperature of the water used to clean the knives and increasing the frequency of the cleaning of the knives between carcasses are possible. Also, the habit of cleaning visibly contaminated carcasses by means of cold water should be abandoned. In general, it can be stated that most steps of the process are well controlled and executed, resulting in only a limited number of carcasses that are contaminated. However, due to certain remaining risk factors, the contamination and cross-contamination of carcasses with *Salmonella* during the slaughter process remain possible. This is also confirmed by the results of the *Salmonella* surveillance and monitoring programm on pig carcasses in Belgian slaughterhouses: 9.3 percent of the carcasses tested positive.

The transformation and distribution

Studies have shown that the cleaning and disinfection of the machines only once a day is not always sufficient (Pala et Sevilla, 2004). According to Bouvet *et al*. (2002), the number of micro-organisms in the working area increase in the course of the day. Therefore, additional cleaning and disinfection during the day is to be advised. According to Berends *et al*. (1998), however, the cleaning and disinfection of surfaces and utensils during breaks and at the end of the working day will most likely prevent not more than about 10% of all cross-contamination. Thus, as long as contaminated carcasses are being processed, about 90% of the cross-contamination that occurs in cutting plants is practically unavoidable.

Manipulation of the meat should be minimized and knives should also be disinfected during the day. In addition, the time-temperature trajectory is important: meat should stay for as short a time as possible in the working area, where the temperature is higher. At the end of the cutting phase, 7.3% of the meat tested positive (Anonymous, 2005).

The consumer

Epidemiological data indicate that a substantial proportion of foodborne disease is attributable to improper food preparation practices in consumers' homes (Redmond and Griffith, 2003). Personal hygiene, adequate cooking and the avoidance of cross-contamination should receive more attention in food safety education programs. Also, meat should be brought home from the store as quickly as possible, and use of a cooling box in the car can prevent the meat temperature from increasing. Lowering the number of persons consuming raw meat (still 20%) might also decrease the risk.

CONCLUSIONS

This study provides qualitative data on the risk for *Salmonella* contamination of pork throughout the Belgian production process. It can be stated that under the current circumstances, fattening pigs transported to the slaughterhouse have a significant risk of being infected with *Salmonella*. At the slaughterhouse, there is a significant risk for pigs becoming infected in the lairage area and for carcasses to become (cross-)contaminated with *Salmonella*. During the processing and distribution phases, the prevalence likely slightly decreases. In the consumer phase, there can again be an increase of *Salmonella* because of the meat not being properly prepared by the consumer.

We conclude at this time that improvement is still needed in the whole production path. Although a lot of measures have already been taken at the primary phase and at the slaughterhouse level, there are still some critical control points left, *e.g.* nose-to-nose contact between different pens, the absence of acidified drinking water, the lack of hygiene, the access of dogs, cats and birds to the stables and the use of the same equipment in the different stables or compartments. At the slaughterhouse level, a second flamer after the polishing and just before arriving at the clean part of the slaughterhouse can ensure that all the *Salmonella* on the carcass surface have been killed. Well trained staff can prevent the contamination of carcasses with gut content. It is also beneficial to disinfect the knives more frequently and at higher temperatures (at least 82°C). Further quantitative studies are required. Educating consumers to control or prevent food-borne disease during shopping, cooking and consumption may further reduce the risk for *Salmonella* infection.

ACKNOWLEDGEMENTS

The authors want to thank the Federal Food Agency of Belgium for its help and their advices. This study has been carried out with the financial support of the Belgian Federal Public Service of Health, Food Chain Safety, and Environment research program (R-04/003-Metzoon) 'Development of a methodology for quantitative assessment of zoonotic risks in Belgium applied to the '*Salmonella* in pork' model'. The authors also want to thank the herds, slaughterhouses and other companies that participated in the study.

REFERENCES

Alban L., Stark K.D. (2005). Where should the effort be put to reduce the *Salmonella* prevalence in the slaughtered swine carcass effectively? *Preventive Veterinary Medicine 68*, 63-79.

Alban L., Olson A.M., Nielsen B., Sörensen R., Jessen B. (2001). Assessment of the human risk associated with use of pork with possible presence of *Salmonella* Ttyphimurium DT104 for dry-cured sausages. *Berliner und Münchener Tierärztliche Wochenschrift 114*(9-10), 366-9.

Anonymous (2002). Règlement (ce) n° 178/2002 du parle-