MICROBIOLOGICAL HAZARDS AND HYGIENE PRACTICES ASSOCIATED WITH MEAT FROM THE DEBONING ROOM OF A GRADE A RED MEAT ABATTOIR

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DECLARATION OF INDEPENDENT WORK

I, SAARTJIE NEL, do hereby declare that this research project submitted for the degree MAGISTER TECHNOLOGIAE: ENVIRONMENTAL HEALTH, is my own independent work that has not been submitted before to any institution by me or anyone else as part of any qualification.

Nel .... 2003-03-18 ....

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ABSTRACT

In this study red meat samples were collected from a deboning room of a grade A abattoir. The samples were analysed for the presence of *Bacillus cereus, Staphylococcus aureus, Pseudomonas* spp., *Listeria monocytogenes, Escherichia coli* and *Salmonella* spp. The total plate counts as well as *Enterobacteriaceae* were also enumerated. The average *B. cereus* count over the sampling period was 8.32 x 10^3 cfu.g^{-1}, for *S. aureus* and *Pseudomonas* spp. 1.72 x 10^5 cfu.g^{-1} and 1.7 x 10^5 cfu.g^{-1} respectively and for *E. coli* 3.4 x 10^5 cfu.g^{-1}. Sixty percent of the samples were positive for presumptive *Salmonella* spp. while 52% of the samples tested positive for the presence of *L. monocytogenes*. The total plate and *Enterobacteriaceae* counts were 1.7 x 10^7 cfu.g^{-1} and 4.6 x 10^6 cfu.g^{-1} respectively. Almost without exception, the counts exceeded the microbiological guidelines for raw meat as proposed by the South African Department of Health. The inter-relationships between the micro-organisms were also determined, and a strong correlation between the total plate counts and *Enterobacteriaceae, Pseudomonas* spp. and *Staphylococcus aureus* was respectively noted.

Because deboning is such a labour and handling intensive process the practices, knowledge and attitudes of the meat handlers regarding personal and general hygiene were assessed by means of a structured questionnaire. The meat handlers were interviewed in their preferred language on aspects relating to personal and general hygiene applied in the deboning room. The results obtained indicated that a need exists for communication between management and workers as well as a need for more training in relation to personal and general hygiene. However, basic personal and hygiene practices such as the wearing of overalls and gumboots, as well as the cleaning and disinfection of equipment are applied, but need to be optimised in order to be effective.

New approaches are being implemented to reduce the occurrence of foodborne disease outbreaks. Risk assessment and HACCP are viewed as concepts that have become increasingly important in ensuring safe food upon consumption. In this study therefore, a stepwise identification procedure for foodborne microbiological hazards was applied to evaluate pathogens associated with deboned vacuum-packaged red meat. The application of the hazard identification procedure resulted in the compilation of a pathogen list which included: *B. cereus, S. aureus,* presumptive *Salmonella* spp., *L. monocytogenes, Clostridium botulinum* and *C. perfringens.* The list also included *Pseudomonas* spp., which are predominantly spoilage micro-organisms. Finally a revised hazard identification flow sheet using information from both empirical data and literature was proposed.

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OPSOMMING

In hierdie studie is rooivleismonsters van 'n ontbeningslokaal van 'n graad A-abattoir versamel. Die monsters is geanaliseer vir die aanwesigheid van *Bacillus cereus*, *Staphylococcus aureus*, *Pseudomonas* spp., *Listeria monocytogenes*, *Escherichia coli* en *Salmonella* spp. Die totale plaattellings, sowel as *Enterobacteriaceae*, is ook verreken. Die gemiddelde *B. cereus*-telling tydens die proefperiode was 8.32 x 10^3 cfu.g^{-1}, vir *S. aureus* en *Pseudomonas* spp., 1.72 x 10^5 cfu.g^{-1} and 1.7 x 10^5 cfu.g^{-1} onderskeidelik, en vir *E. coli* 3.4 x 10^5 cfu.g^{-1}. Sestig persent van die monsters was positief vir waarskynlike *Salmonella* spp., terwyl 52% van die monsters positief getoets het vir die aanwesigheid van *L. monocytogenes*. Die totale plaat- en *Enterobacteriaceae*-telling was 1.7 x 10^7 cfu.g^{-1} en 4.6 x 10^6 cfu.g^{-1} onderskeidelik. Die tellings het feitlik sonder uitsondering die mikrobiologiese riglyne vir rou vleis, soos voorgestel deur die Suid-Afrikaanse Departement van Gesondheid, oorskrei. Die onderlinge verhoudings tussen die mikro-organismes is ook bepaal en 'n sterk korrelasie is gevind tussen die totale plaattellings en *Enterobacteriaceae*, *Pseudomonas* spp. en *S. aureus*, onderskeidelik.

Aangesien ontbening so 'n arbeids- en hanteringsintensiewe proses is, is die praktyke, kennis en houdings van die vleishanteerders aangaande persoonlike en algemene higiëne geassesseer deur middel van 'n gestruktureerde vraelys. Die vleishanteerders is in hul taal van voorkeur ondervra aangaande aspekte wat verband hou met persoonlike en algemene higiëne, wat van toepassing is in die ontbeningskamer. Die resultate wat verkry is, het aangedui dat daar 'n behoefte aan kommunikasie bestaan tussen die bestuur en werkers, asook 'n behoefte aan meer opleiding in verband met persoonlike en algemene higiëne. Basiese persoonlike en higiëne-praktyke, soos die dra van oorpakke en rubberskoene, asook die skoonmaak en ontsmetting van toerusting word toegepas, maar moet geoptimiseer word om effektief te wees.

Nuwe benaderings word geïmplementeer om die voorkoms van siekte-uitbrake vanweë voedsel te verminder. Risiko-assessering en HACCP word beskou as konsepte wat toenemend belangrik word in die versekering van veilige voedsel met inname. Om die rede is daar in hierdie studie 'n stapsgewyse identifikasieprosedure vir mikrobiologiese gevare wat deur voedsel versprei toegepas, om patogene te evalueer wat geassosieer word met ontbeende vakuumverpakte rooivleis. Die toepassing van die gevaaridentifikasieprosedure het die samestelling van 'n patogenelys tot gevolg gehad wat die volgende insluit: *B. cereus*, *S. aureus*, waarskynlike *Salmonella* spp., *L. monocytogenes*, *Clostridium botulinum* en *C. perfringens*. Die lys sluit ook *Pseudomonas* spp. in, wat meerendeels bederf-organismes is. Laastens is 'n hersiende gevaaridentifikasievloeikaart met inligting van beide die empiriese data en die literatuur, voorgestel.

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CHAPTER 1

INTRODUCTION

1. INTRODUCTION

1.1 HISTORICAL REVIEW

From as early as the 15th century stock-farming played an important role in the history and development of South Africa. From the time of the establishment of the Cape as a refreshment station, the Portuguese exchanged copper trinkets and other articles with the Hottentots for fresh meat which was necessary for the long voyage to India (Samic, 2002).

Today, five centuries later, the meat industry is the largest agricultural industry in South Africa, with almost 70% of the country's surface suitable for stock-farming. This industry contributes over 40% of the total value of agricultural production (Samic, 2002). Table 1 summarises the meat product against the per capita consumption.

Previously "slaughter poles" was the term used to designate an abattoir. "Slaughter poles" generally consisted of two upright poles with a horizontal crossbar on to which the animal could be hoisted. As a result of the growing population and increased awareness of hygiene and foodborne disease, however, increased demands were imposed on meat producers with regard to good manufacturing practices. This subsequently rendered the "slaughter poles" inadequate for slaughtering, which led to the construction of a facility known as an abattoir. The word "abattoir" was borrowed from the French, and means a modern professional type of slaughtering facility (Van Zyl, 1995).

Traditionally South African abattoirs were managed by local authorities, during which time they offered a slaughtering service to the community. Today abattoirs are owned privately, and the abattoir fulfils both an integrated and wholesale function, and entails the sourcing of animals on the hoof and the direct selling of carcasses and meat cuts to the retail market (Van Zyl, 1995).

Table 1. The annual average per capita consumption of meat products in South Africa (adopted from Samic, 2002).

Product	**Consumption per capita (kilogram per year)**
Beef and veal	12,4
Lamb, mutton and goat	3,6
Pork	3,2

According to Aberle *et al.* (2001), the consumption of meat has played a significant role throughout the history of man in the social and economic prestige of people and nations. As a country becomes more industrialised the consumption of meat shows the same tendency.

1.2 FOODBORNE DISEASE

Foodborne diseases have been known to mankind since biblical times and long before the time of Christ. Moses, for example, commanded the Israelites (Leviticus. 11:39) not to eat meat from diseased animals (Morse *et al.*, 1994). Furthermore Moses made laws to protect his people against disease: one of these laws was the washing of hands after killing sacrificial animals and also before consuming food.

According to the World Health Organisation (WHO) (1989) illness resulting from eating contaminated food is considered the most widespread health problem in the contemporary world and thus an important cause of reduced economic productivity. The WHO (1989) further reports that food contamination by biological agents is recognised as a major public health problem all over the world.

Foodborne disease has been defined as "a disease of an infectious or toxic nature caused by or thought to be caused by, the consumption of food or water" (Adams and Moss, 1997). According to Frazier and Westhoff (1988) the term *food poisoning*, as applied to diseases caused by micro-organisms, is used very loosely to include both illnesses caused by the ingestion of toxins elaborated by the organisms and those resulting from infection of the host through the intestinal tract.

Foodborne diseases are subdivided into poisonings and infections where food poisoning can be the result of either chemical poisoning or the ingestion of a toxin which is referred to as intoxication (Aberle *et al.*, 2001). The toxin may be found naturally in certain plants or animals, or may be a toxic metabolic product excreted by a micro-organism (Frazier and Westhoff, 1988). Bacterial food intoxication therefore refers to foodborne illnesses caused by the presence of a bacterial toxin formed in the food. A bacterial food infection refers to foodborne illnesses caused by the entrance of bacteria into the body through ingestion of contaminated foods and the reaction of the body to their presence or to their metabolites (Aberle *et al.*, 2001). Forsythe and Hayes (1998) report that the majority of illnesses found, result from the consumption of contaminated food or drink, caused by infection with or the presence of bacteria.

Clinically, certain features help to characterise these forms of intoxication. These features include the interval between ingestion of the contaminated food and the onset of the first symptoms (Forsythe, 2000). The symptoms may include the following: diarrhoea, fever, malaise, stomach and abdominal cramps, headache, muscle cramps, nausea and vomiting. The onset is generally only a matter of hours. Usually, several persons who have shared the same meal are poisoned at the same time, but the degree of intoxication depends on the amount of the tainted food consumed and the sensitivity of the individual to the toxin (Jay, 1996). Individuals showing symptoms are referred to as symptomatic carriers, while asymptomatic carriers are those who do not present symptoms of the disease but carry the causative agent, for example *Listeria monocytogenes* in the case of listeriosis.

Potentially, anyone is at risk from the effects of food poisoning, although certain groups are more susceptible than others. According to the Centre for Disease Control (2002), the incidences of foodborne diseases in 2001 varied according to age. Infants and young children had the highest incidence of foodborne infections. The rates were highest in children aged <1 year for *Salmonella* (134.1 per 100 000 children) and *Listeria* (1.9). The incidence of *Listeria* cases in persons aged >75 years (1.7) was similar to the incidence in infants. These groups are referred to as *immunocompromised* and these "at risk" groups, according to the Food Safety Advisory Centre (1993), include:

- babies and infants (under two years),
- pregnant women and their unborn children,
- elderly people,
- those who are already ill or are convalescing,
- those who are taking drugs which suppress their body's natural ability to fight infection,
- those on extensive treatment with antibiotics or receiving chemotherapy, and
- those with reduced natural ability to fight infection such as AIDS sufferers, alcoholics, drug abusers, diabetics and transplant patients.

The various types of food poisoning are generally associated with specific foods; however there is ample evidence to show that the foods most commonly implicated in food poisoning in general are the various meats (Forsythe and Hayes, 1998). The micro-organisms frequently associated with various kinds of food products are summarised in Table 2.

1.2.1 Intrinsic and extrinsic factors affecting microbial growth

The characteristic development of microbiological populations in meat is the result of the surrounding environmental conditions on the types of micro-organisms which are present on the raw meat or which are introduced by cross-contamination or processing (Gill and Jones, 1999). The factors that affect the growth of the micro-organisms are either intrinsic or extrinsic factors. Intrinsic factors include the concentration or availability of nutrients, pH, redox potential, the buffering capacity and the availability of water, anti-microbiological constituents and biological structures: thus all factors or parameters that are inherent part of the tissues. Furthermore extrinsic parameters are more concerned with storage and processing conditions: parameters that affect both the product and the micro-organisms and include temperature of storage, the relative humidity of the environment and the presence and concentration of gases in the environment (Brown, 1982; Jay, 1996; Gill and Jones, 1996).

Table 2. Agents of foodborne diseases and examples of incriminated food products (Food Safety Advisory Centre, 1993; Notermans and Borgdorff, 1997).

Agent	Food product
Bacillus cereus	Boiled and fried rice, cereal products and cooked meats
Staphylococcus aureus	Poultry, fish, meat, milk, cream, custard and sauces
Pseudomonas spp.	Fresh and processed meats and fish
Listeria monocytogenes	Milk (dairy products) and meat including fish, poultry and eggs
Escherichia coli	Cold foods: sandwiches and salads, undercooked foods, meat and meat products
Salmonella spp.	Meat and meat products, poultry, eggs, milk and milk products

1.3 MEAT AS A MEDIUM FOR MICROBIAL CONTAMINATION

Meat composition, as well as the processes involved in meat production, is of special consideration in rendering a safe and hygienic product to the consumer (Wood *et al.*, 1998). Foods prepared from animal products represent concentrated sources of most of the nutrients required by man. Therefore meat is one of the most nutritious foods, because it is a particularly rich source of high-quality protein, iron, essential B vitamins and vitamin A (Aberle *et al.*, 2001).

Adams and Moss (1997) report that the term *meat* was originally used to describe any solid food, but has now come to be applied almost solely to animal flesh which comprises principally of the muscular tissues, but also include organs such as the heart, liver and kidneys. According to Aberle *et al.* (2001) meat can be subdivided into several categories: beef, pork, lamb, mutton and veal are commonly referred to as red meat, whereas poultry meat is the flesh of chickens, turkeys, ducks and geese. Seafoods include the flesh of aquatic organisms such as fish, clams lobster, crabs, mussels and other shellfish. The fourth category is game meat such as venison, and in principal this category consists of the flesh of any non-domesticated animal.

The composition of meat renders it the most perishable of all-important foods (Jay, 1996). The chemical composition of meat is given in Table 3. Fresh meat has pH values within the growth range of most micro-organisms listed in Table 2. The oxidation-reduction potential on the surface of processed meat tends to be higher than in the case of whole meat, which results in suitable growth conditions for strict aerobes and facultative anaerobes. In addition antimicrobial constituents are not known to occur in meat or meat products, rendering this a perfect growth medium for micro-organisms (Jay, 1996).

Table 3. The chemical composition of red meat (Jay, 1996).

Component	Value in %
Water	75.5
Protein	18.0
Fat	3.0
Amino acids	0.35
Glycogen	0.10
Glucose	0.01
Potassium	0.35
Sodium	0.05
Magnesium	0.02

Meat undergoes many operations before it hangs dressed in cold stores and skilled workers perform these operations with great speed (Figure 1). The animals are stunned by a captive bolt pistol from where the throat of the animal is cut. The animals are then suspended from an overhead rail for the dressing operation, in which the hide and internal organs are removed, followed by various trimming procedures further along the line (Lawrie, 1998). By the time it reaches the end of the chain the carcasses are "dressed" and ready for chilling, classification and further processing. After slaughtering and dressing the carcasses are inspected by an Environmental Health Practitioner to confirm its fitness for human consumption (Van Zyl, 1995).

Muscle tissue from a healthy animal is sterile, but due to the post-mortem handling as discussed in the previous paragraph, contamination by micro-organisms on both the surface and interior tissue of the meat occurs (Frazier and Westhoff, 1988; Hinton *et al.*, 1998). During bleeding, skinning and cutting the main sources of contamination are the exterior from the animal (hide, hooves and hair) and the intestinal tract. The exterior of the animal harbours large numbers of many kinds of micro-organisms originating from soil, water, feed and manure as well as its natural surface micro-organisms; furthermore the animal's intestinal contents also contains various intestinal micro-organisms (Jordan *et al.*, 1999). Knives, cloths, air, hands and clothing of meat handlers can also serve as intermediate sources of contamination (Gill and Jones, 1999). The knowledge of sources of infection and the spreading and control of microbiological growth is therefore of the utmost importance for the effective implementation of hygiene measures (Nottingham, 1982; Untermann *et al.*, 1997).

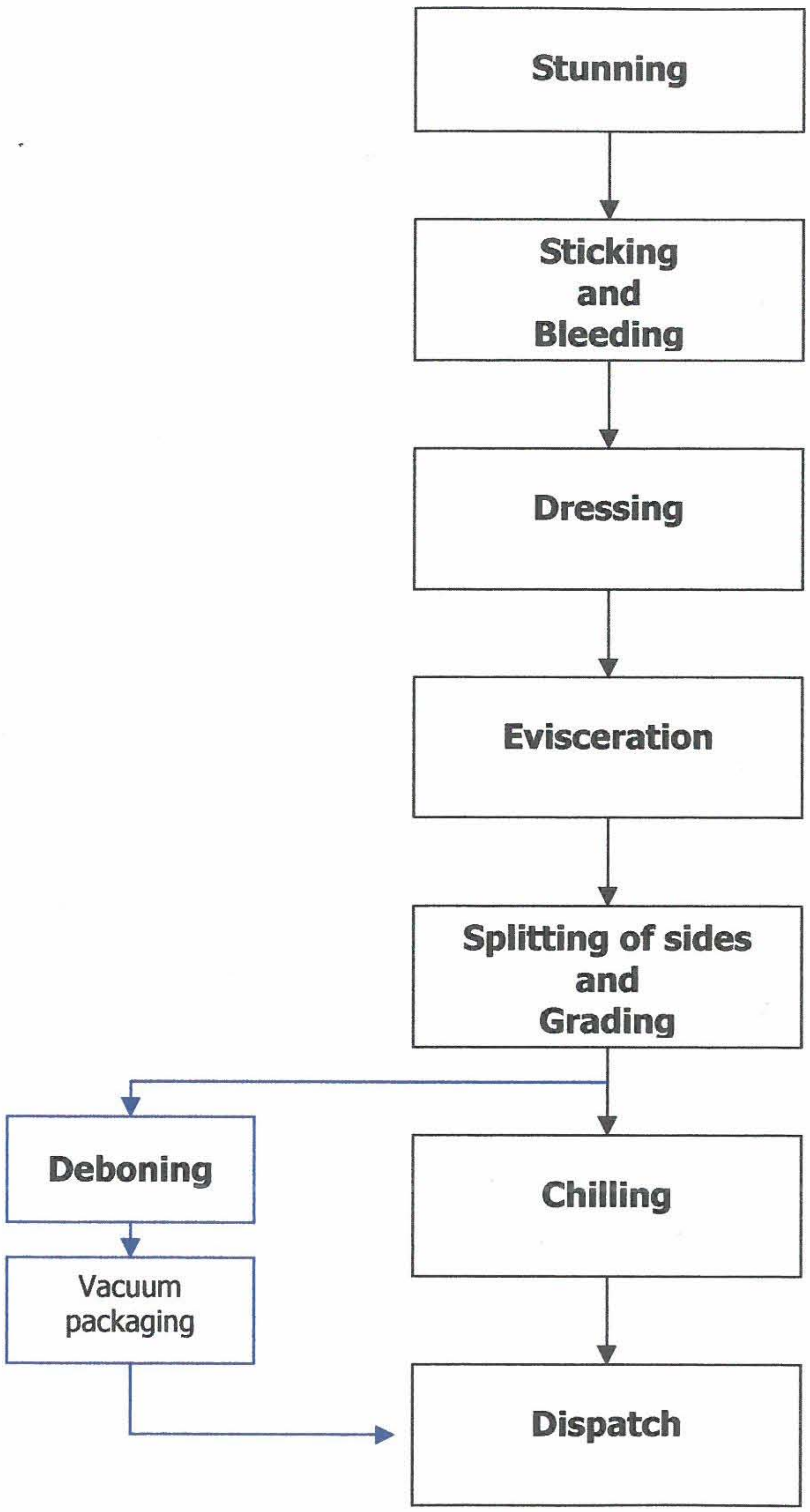

Figure 1: Schematic representation of the slaughtering line for bovine animals (Church and Wood, 1991)

A process that involves extensive post-mortem handling is the deboning of meat (Gill and Jones, 1999). Deboning, which is illustrated in Figure 2, involves the removal of the meat from the skeletal bones and then the cutting of the meat into retail cuts such as loins, rump or sirloin. The bone by-products are then sold for use as bone-meal and other products (Van Zyl, 1995). This meat is then conveyed to a vacuum-packaging and boxing section, after which it leaves for the retail market. Vacuum-packaging is the process by means of which retail cuts are packaged in laminates under oxygen-depleted atmospheres (Gill, 1996). This process is advantageous for the retardation of bacterial spoilage and the retention of the attractive fresh appearance of the meat. Vacuum-packaging therefore increases the shelf-life of the retail cuts (Gill, 1996; Lee and Yoon, 2001).

Foodborne diseases are amongst the most widespread of health problems in the contemporary world, with food being thought to be a major route of transmission (Republic of South Africa, 1999). Therefore the need exists to quantify the situation regarding foodborne diseases and also to verify the necessity for the implementation of methods to prevent and control outbreaks not only in South Africa but also worldwide (Vorster *et al.,* 1994; Wood *et al.*, 1998; Jordan *et al.*, 1999). Figure 3 illustrates reported cases of foodborne diseases within South Africa from 1992 to 2001. During 2001, a total of 13,705 laboratory-diagnosed cases of 10 foodborne diseases under surveillance in the United States was identified: 5,198 of *Salmonella* spp. infection, 4,740 of *Campylobacter* spp., 2,201 of *Shigella* spp., 574 of *Cryptosporidium* spp., 565 of *E. coli* O157, 145 of *Yersinia* spp., 94 of *Listeria* spp., 80 of *Vibrio* spp., 32 of *Cyclospora* spp. (Centre for Disease Control, 2002). According to Vorster *et al.* (1994) and Notermans and Borgdorff (1997) the United Kingdom has shown a marked increase in notifications since the middle 1960s. In South Africa

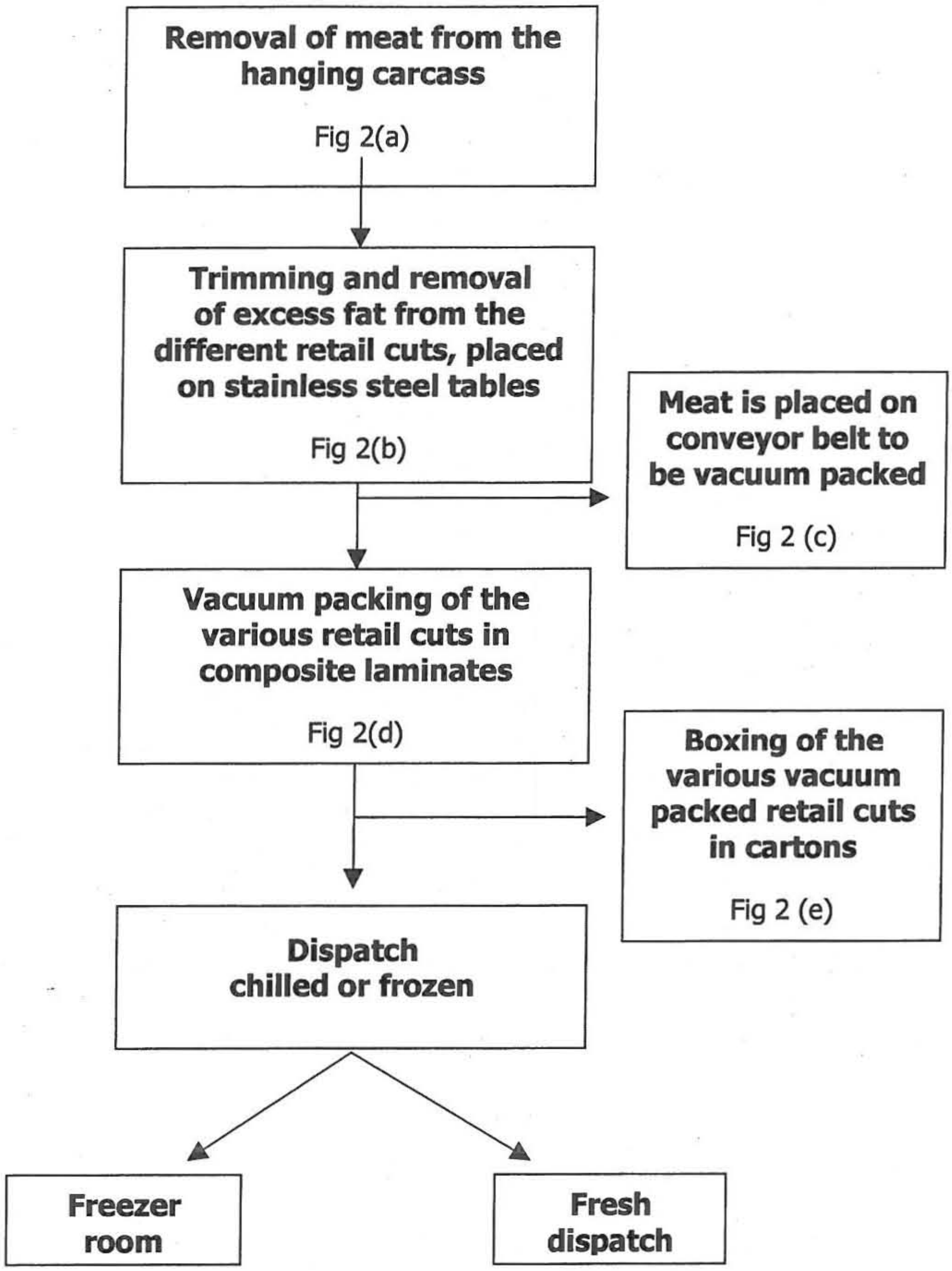

Figure 2: Schematic representation of the deboning process at a red meat abattoir.

Figure 2(a): The removal of retail cuts from the hanging carcasses.

Figure 2 (b): Trimming excess fat from retail cuts on stainless steel tables.

Figure 2 (c): Placement of retail cuts on the conveyor belt for vacuum-packaging.

Figure 2 (d): The vacuum-packaging process of the retail cuts.

Figure 2 (e): Boxing of the retail cuts for transportation or freezing.

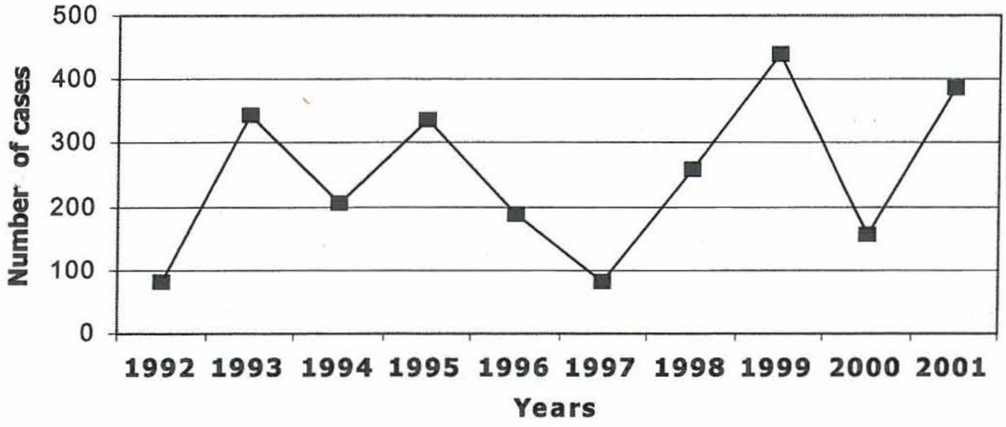

Figure 3: Foodborne illness cases between 1992 and 2001 reported in South Africa (Republic of South Africa, 2002).

foodborne diseases only became notifiable in December 1989. Vorster *et al.* (1994) further reports that notifications of foodborne diseases in the South African context are further hampered because of the fact that notifications are only required when five or more cases are reported by one physician or medical institution; thus the actual occurrence of foodborne diseases is not reflected.

1.4 SELECTED MEATBORNE MICRO-ORGANISMS FREQUENTLY ASSOCIATED WITH DISEASE OUTBREAKS AND FOOD SPOILAGE.

Bacillus cereus

Bacillus cereus is one of the few spore-forming, aerobic bacteria recognised as a food pathogen (Forsythe, 2000). The organism is one of the pathogens most frequently associated with foodborne outbreaks, with the earliest outbreak being reported in 1906 (Nortjé *et al.*,1999; Borch and Arinder, 2002). *B. cereus* is a large flagellated Gram-positive rod. This organism is capable of growing over a wide temperature range varying from 10°C – 48°C with an optimum range of 28°C – 35°C (Lattuada and McClain, 1998). Due to the ubiquitous nature of this organism, it would appear impossible to obtain raw products that are free from it (Schultz and Smith, 1994). In addition *B. cereus* is able to produce a toxin while growing and multiplying on food. Although this organism is usually present in rice, cereals, corn flour, meat, poultry, soil, milk, herbs and spices (Trickett, 1992), according to a study by Mosupye and Von Holy (2000) on South African street foods, *B. cereus* was the most prevalent pathogen (17%) in both raw and cooked meat samples.

Two distinct types of illness are caused by *B. cereus*. The first is denoted as diarrhoeal illness with symptoms including abdominal pain and diarrhoea, whereas the second is referred to as emetic illness that is characterised by nausea and vomiting. The latter type is furthermore associated with cereal products, while the diarrhoeal type is associated with a wide range of foods (Forsythe, 2000).

Staphylococcus aureus

According to Borch and Arinder (2002) foodborne illness associated with *S. aureus* remains a major problem worldwide. Bennett and Lancette (1995) and Portocarrero *et al.* (2002) report that *S. aureus* has been identified as the causative agent in many foodborne diseases therefore probably being responsible for more cases than recorded. Raw meat is commonly contaminated with large numbers of the organism because of its presence in the environment and on food handlers' hands (Desmarchelier *et al.*, 1999; Mosupye and Von Holy, 2000). *S. aureus* is Gram-positive, facultative anaerobic, cocci (1 µm diameter). Only certain strains of *S. aureus* are said to cause foodborne disease, these include enterotoxin producers (Pelczar *et al.*, 1993; Aberle *et al.*, 2001). The habitat of *S. aureus* includes the skin, skin glands and the mucous membranes of warm-blooded animals, with humans considered to be its principal reservoir in nature (Martin and Myers, 1994; Adams and Moss, 1997; Desmarchelier *et al.*, 1999). Trickett (1992) reports that this organism is heat labile and is destroyed within one or two minutes in boiling water. The toxins produced by *S. aureus*, however, are more stable and can survive for up to 30 minutes in boiling water.

The onset of symptoms in Staphylococcus food poisoning is usually rapid and acute, depending on the susceptibility of the host to the toxin, the amount of contaminated food and toxin consumed as well as the general health of the individual (Bennett and Lancette, 1995). General symptoms of toxin ingestion include nausea, vomiting, retching, abdominal cramps and prostration; further symptoms of more severe cases include headaches, muscle cramping and transient changes in blood pressure and pulse rate (Bennett and Lancette, 1995). Staphylococcal food poisoning also affects the central nervous system, although death seldom occurs; where death does occur it is usually in immunocompromised individuals (Aberle *et al.*, 2001).

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Escherichia coli

Escherichia coli is almost an universal inhabitant of the gut of humans and other warm-blooded animals, where it helps to maintain the normal physiological function of the intestines (Neill *et al*., 1994; Adams and Moss, 1997). Therefore this organism may be isolated from foods of animal origin, which include meat, milk and eggs (Hobbs and Roberts, 1993). Until the late 1950s *E. coli* was claimed to be non-pathogenic; however some strains were later found to be pathogenic (Vorster *et al*., 1994; Garbutt, 1997). *E. coli* is a short gram-negative, non-spore-forming rod and is a typical mesophile, growing at temperatures between 7°C – 10°C as well as at temperatures of up to 50°C, with an optimum of 37°C (Adams and Moss, 1997). *E. coli* is accepted as an indicator of the behaviour of the mesophilic and enteric pathogens associated with meats, therefore giving an indication of faecal contamination and general hygiene levels (Gill *et al*., 1995; Gill *et al*., 1998).

E. coli strains are generally divided into the following groups (Forsythe, 2000):

- Enteropathogenic
- Enterotoxigenic
- Enteroinvasive
- Enterohaemorrhagic and
- Facultatively enteropathogenic

These strains can cause acute gastro-enteritis with the following symptoms: abdominal pain, fever, vomiting and diarrhoea that may be prolonged and bloody with mucus in the stools (Jacob, 1989).

Listeria monocytogenes

Listeria monocytogenes, the causative agent of listeriosis that was discovered almost 100 years ago, has emerged as a significant public health problem and has caused several epidemics worldwide (Donnelly, 1994). *L. monocytogenes* has also been implicated in diseases caused by meat products such as fish, seafood and vegetables amongst others (Fantelli and Stephan, 2001). Therefore an extensive surveillance programme and outbreak data exists for *L. monocytogenes* (U.S. Food and Drug Administration, 1992).

The organism is a short (0.5 µm in diameter by 1 µm to 2 µm long) Gram-positive, facultative anaerobic, motile, non-spore-forming rod (Forsythe and Hayes, 1998). It is also associated with a variety of environments that include soil, water, sewage, silage and also plant and animal food products (Nesbakken *et al.*, 1996; Cook, 1998). *L. monocytogenes* grows at temperatures of between 1°C and 45°C with an optimal growth temperature between 30°C and 37°C. Furthermore the presence of *L. monocytogenes* is of particular concern in meat because of its ability to grow at refrigerated temperatures and its resistance to heat and curing salts. Furthermore the abattoir environment and slaughtering practices are more implicated than faeces and skin of animals as a source of *L. monocytogenes* (Nesbakken *et al.*, 1996). The organism is associated with both raw and cooked meat and because it is cold-tolerant it may thus be regarded as an appropriate indicator for the behaviour of cold-tolerant pathogens in meat (Gill *et al.*, 1995).

Research has shown that 1% - 9% of the human population carries *L. monocytogenes* in their faeces, most of those individuals thus being asymptomatic carriers. Although Listeriosis may be a life-threatening illness in immunocompromised individuals, it is of minimal concern in a healthy individual

(Ryser and Marth, 1991; Samelis and Metaxopoulos, 1999). The following clinical manifestations and symptoms are characteristic of Listeriosis:

- septicaemia and meningitis;
- pregnant woman: flu-like symptoms, premature labour, stillbirth or early death of the newly born infant; and
- acute, mild febrile illness (Benenson, 1995; Forsythe and Hayes, 1998; Borch and Arinder, 2002).

***Salmonella* spp.**

According to Bacon *et al.* (2002) *Salmonella* spp. is regarded as the most important causative agent of foodborne disease in many countries and research has highlighted poultry and red meat as major role players in human Salmonellosis. *Salmonella* spp. are small, motile, non-spore-forming, facultative anaerobic, Gram-negative rods with a maximum growth temperatures of 45°C – 47°C, a minimum growth temperature of 5.1°C and an optimum growth temperature of 37°C (Mortimore and Wallace, 1994). Various well-known species are included within the *Salmonella* genus i.e. *S. enteritidis, S. typhimurium, S. heidelberg, S. derby, S. java*. (Frazier and Westhoff, 1988). Reservoirs of *Salmonella* include humans, cattle, poultry, eggs and fish (Bacon *et al.*, 2002).

The disease Salmonellosis is characterised by:

- Gastro-enteritis: inflammation of the stomach and intestines with accompanying abdominal pain, headache, nausea, vomiting and diarrhoea.
- Typhoid Fever: constipation, intestinal haemorrhage, enlarged spleen and lymph nodes and sustained fever (Burton, 1996; Nzimande, 1997).

Ziprin (1994) reports that beef, chicken and egg products are responsible for the largest proportion of human salmonellosis outbreaks of known origin.

***Pseudomonas* spp.**

These organisms represent the largest genus of spoilage bacteria that exists in fresh foods (Eisel *et al.*, 1997). *Pseudomonas* spp. are Gram-negative, usually motile, asporogenous rods (Frazier and Westhoff, 1988). Their reservoirs include soil, water, vegetables, meat, poultry and seafood products. *Pseudomonas* spp. are psychrotrophic which enables them to multiply and grow at refrigerated temperatures (Jay, 1996; Buys *et al.*, 2000). Research has shown that *Pseudomonas* spp. predominate in fresh meat stored aerobically at chilled temperatures (Gill, 1996; Aberle *et al.*, 2001). *Pseudomonas* spp. include amongst others some of the following species: *P. aerugonosa, P. agarici, P. fluorescens, P. cichorii, P. corrupata, P. fragi* (Garbutt, 1997). *Pseudomonas* is known to cause illness in immunocompromised individuals if consumed in large numbers (Pelczar *et al.*, 1993).

Enterobacteriaceae

The family *Enterobacteriaceae* which are facultatively anaerobic bacteria with the ability to ferment carbohydrates, are comprised of many genera that include lactose fermenters such as *Escherichia* spp. and *Enterobacter* spp. and the non-lactose fermenting group that includes *Proteus* spp., *Serratia* spp., *Salmonella* spp. and *Shigella* spp. (Hayes, 1985). These organisms are found in animal intestines, soil and plants, from where they can contaminate the human food chain. The coliform group and *E. coli* are generally regarded as indicator organisms of faecal contamination if present in excess numbers. Furthermore, *Salmonella* spp., *Shigella* spp. and some strains of *E. coli* cause types of gastroenteritis that differ in severity (Church and Wood, 1991; Murray *et al.*, 2001).

1.5 APPROACHES REGARDING MEAT HYGIENE AND SAFETY CONTROL AND THE ROLE OF HAZARD IDENTIFICATION

Morales and McDowell (1998) report that the current food safety and quality assurance systems are continuously exposed to new public health problems. These problems include risks from emerging and re-emerging pathogens and also the increased integration and internationalisation of the food supply. In addition the traditional meat safety and hygiene programmes which focus on ante- and post-mortem inspection are regarded as inadequate (Brown *et al.*, 2000). Microbiological and chemical contamination are considered the important sources of hazards, rather than the grossly apparent abnormalities which are detected by means of organoleptic inspection (Hathaway, 1993). Therefore the regulatory authorities are forced to adopt more scientific and systematic approaches to meat hygiene to ensure that the increasing demands of the consumers in relation to meat hygiene and safety are met (Hathaway, 1993; Berends *et al.*, 1997; Brown *et al.*, 2000). Thus solutions to these emerging food safety problems require new approaches. Several strategies have therefore been developed over the last twenty years to protect the consumer and to produce microbiologically safe food. Figure 4 illustrates some of the recently developed concepts (Notermans *et al.*, 1996). The three major strategies according to Notermans *et al.* (1996) include Good Manufacturing Practices (GMP), Hazard Analysis Critical Control Point (HACCP) and Risk Analysis. Notermans *et al.* (1998) furthermore mention that the production of safe food is based on the use of good quality raw materials and the application of GMP and HACCP. The authors suggest that the risk analysis approach is becoming the new cornerstone in producing acceptable, safe food.

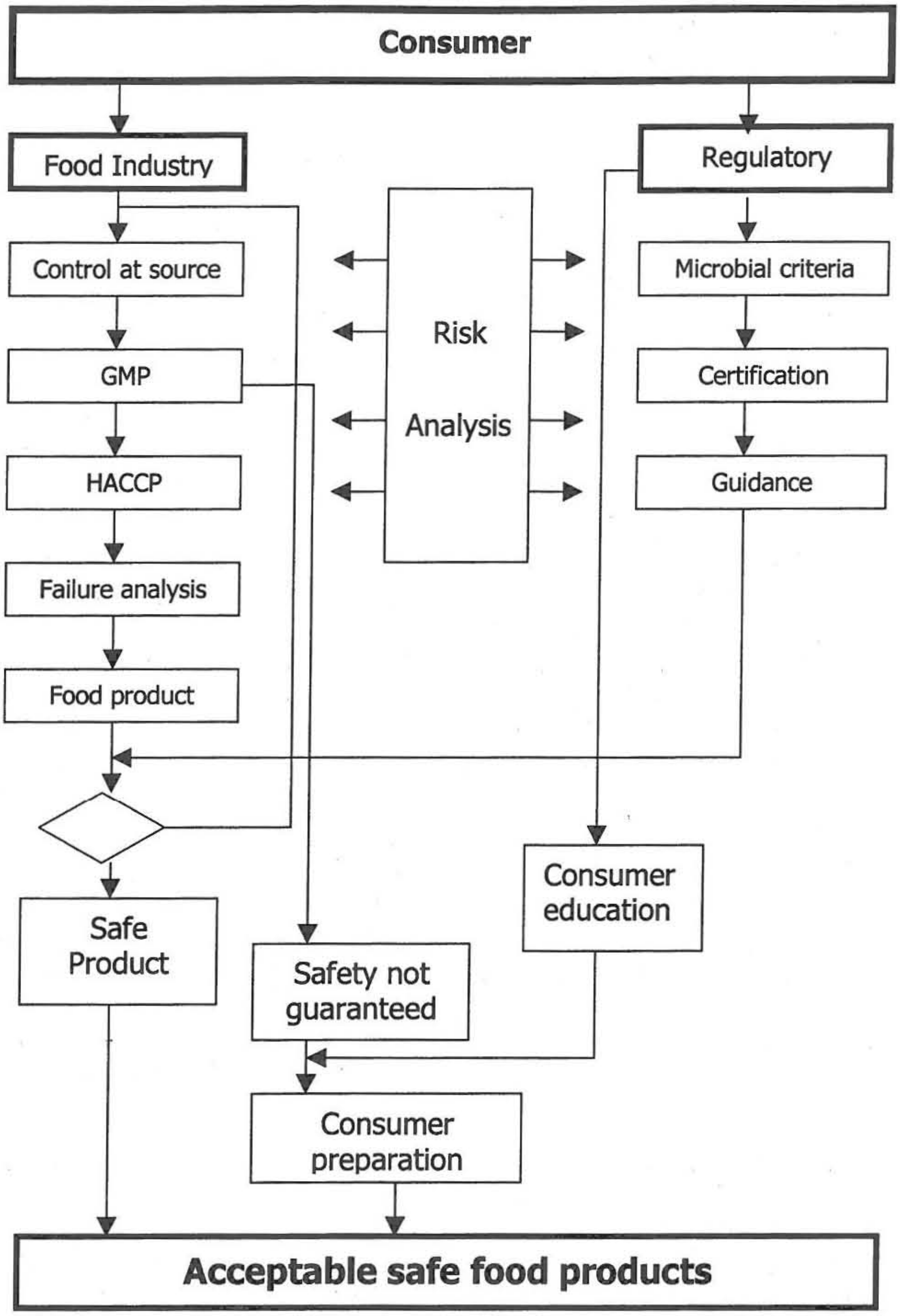

Figure 4: Concepts developed for the production of microbiologically safe food (Notermans *et al.*, 1996).

Risk analysis, is an applied science based on scientific and technical information, which also includes social and political policy decisions (Hathaway, 1993). Foegeding (1997) and Lammerding (1997) report that risk analysis consists of three concepts: risk assessment, risk management and risk communication. The first concept, risk assessment, can be defined as the characterisation of potentially adverse effects of exposure to hazards which includes estimates of the magnitude of the risk, the severity of the outcome and the indication of the uncertainties involved (Potter, 1996; Buchanan, 1997). Risk assessment consists of the following steps: hazard identification, exposure assessment and risk characterisation (Foegeding, 1997; Notermans *et al.*, 1997).

The aim of the second concept, risk management, is to reduce the probability of the occurrence of an unacceptable risk (Notermans *et al.*, 1996). The remaining concept, risk communication, may be defined as the science of understanding scientific and technological risk and how it is communicated within a socio-political structure (Powell, 1999). Figure 5 illustrates the diagrammatic representation of risk analysis.

Lammerding and Paoli (1997), the National Advisory Committee on Microbiological Criteria for Foods (1998) and the World Health Organisation (1999) define the four steps of risk assessment as follows:

Hazard identification:	The identification of biological, chemical and physical agents capable of causing adverse health effects and which may be present in a particular food or group of foods.

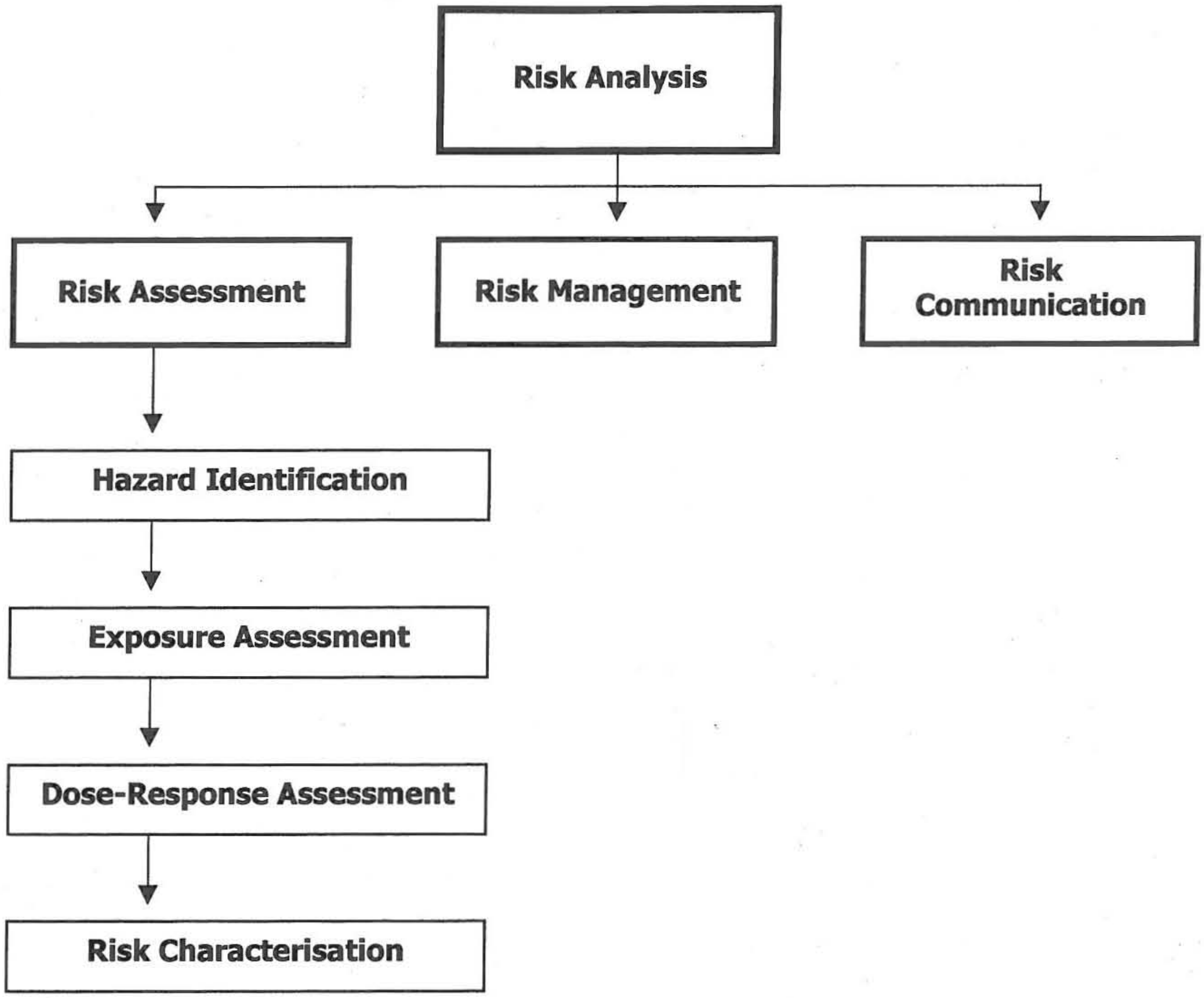

Figure 5: Concepts of risk analysis (Notermans and Teunis, 1996).

Exposure assessment:	The qualitative and/or quantitative evaluation of the likely intake of biological, chemical and physical agents via food as well as exposures from other sources if relevant.
Dose-Response assessment:	The determination of the relationship between the magnitude of exposure (dose) to a chemical, biological or physical agent and the severity and/or frequency of associated adverse health effects (response).
Risk characterisation:	The process of determining the qualitative and/ or quantitative estimation, including attendant uncertainties, of the probability of occurrence and severity of known or potentially adverse health effects in a given population based on hazard identification, exposure assessment and dose-response assessment.

Notermans *et al.* (1998) mention that for microbial risk assessment the purpose of hazard identification would be to identify the micro-organisms or the microbial toxins of the food concerned. According to Lammerding and Fazil (2000) hazard identification would predominately be a qualitative process which is a descriptive or categorical treatment of information and may be undertaken as a first evaluation of a food safety issue to determine whether the risk is significant enough to warrant a more detailed analysis.

The ultimate goal of food safety assurance approaches as described by Potter (1996), is to ensure that the food consumed is acceptable and safe. In addition, public confidence will be won, if these approaches are successfully applied. The opposite may however occur if poorly conceived applications lead to poor results (Potter, 1996).

1.6 RATIONALE

1.6.1 Problem statement

Various inspection programs have been designed to help ensure the safety of meat products delivered to the marketplace. Nevertheless, various human diseases have been linked to the consumption of meat products contaminated with pathogenic micro-organisms. Because the effects of these diseases are usually short-lived and often confused with other illnesses, only a fraction of the cases are reported. The pain and discomfort produced, however, may be severe and in some cases the diseases can be fatal. Therefore risk assessment can be used to list possible hazards and to suggest methods to minimise them (Peeler and Bunning, 1994). Meat hygiene provides a very fertile ground for a risk assessment approach. The procedures applied during on-line inspection do not guarantee meat that is free from grossly detectable abnormalities and micro-organisms and therefore this scientific assessment of health consequences provides a basis for risk assessment.

The purpose of the study is therefore:

- to quantify the potential spoilage bacteria and pathogens on deboned meat from the deboning room of a grade A abattoir, to be able to give an valuable contribution to the hygiene management of the deboning room;
- to assess the personal and general hygiene practices of the workers employed inside the deboning room; and
- to conclude on the identification of potentially hazardous micro-organisms through making use of a hazard identification flow sheet.

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CHAPTER 2

THE PERSONAL AND GENERAL HYGIENE PRACTICES IN THE DEBONING ROOM OF A RED MEAT ABATTOIR

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The personal and general hygiene practices in the deboning room of a red meat abattoir

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Abstract

Food handling facilities are under increased consumer and regulatory pressures to improve the microbiological safety of perishable raw and ready-to-eat commodities. In this study workers from a deboning room of a grade A abattoir were interviewed, by means of a structured questionnaire, to ascertain the knowledge, beliefs and attitudes regarding personal and general hygiene. The workers were interviewed on aspects relating to personal and general hygiene applied in the deboning room. It was found that there are hygiene practices in place and that the workers adhere to the majority of the hygiene practices. The results obtained indicated that there exists a need for improved communication between management and workers as well as a need for more training in relation to personal and general hygiene. Although, basic personal and hygiene practices such as the wearing of overalls and gumboots, as well as the cleaning and disinfection of equipment are applied, they need to be optimised to be effective. It is therefore advisable for all the requirements pertaining to personal and general hygiene to be re-evaluated and implemented by management to ensure that the workers inside the deboning room do not contribute to the contamination of the product.

Saartjie Nel

1. INTRODUCTION

According to Gordon-Davis (1998) a major risk of food contamination originates from the working practices of food handlers and disease-causing micro-organisms present in or on the food handler's body are subsequently transported from the food handler to the food during the handling process. Frazier and Westhoff (1988) report that humans shed about 1×10^3 - 1×10^4 viable micro-organisms per minute. They add that a relationship exists between the numbers and types of such organisms and the working environment. Forsythe (2000) mentions that an estimated one in every 50 food handlers sheds around 10^9 pathogens per gram of faeces without showing any clinical manifestations of the related illness. Subsequently, poor personal hygiene practices such as neglecting to wash hands after visiting the toilet, may result in up to 10^7 pathogens under the fingernails of the food handler. Organisms derived from infected food handlers include *Salmonella* spp., *Shigella* spp., *Escherichia coli, Staphylococcus aureus, Bacillus cereus* and faecal streptococci (Lawrie, 1998).

Because meat is such a highly perishable foodstuff and the abattoir, particularly the deboning room, is such a labour-intensive working environment, the knowledge, education and training of the food handlers on personal and general hygiene is of particular importance to ensure the health and safety of the consumer (Van Zyl, 1995; Jay, 1996). Furthermore Martínez-Tomé *et al.* (2000) highlight the education of food handlers as a crucial line of defence in the prevention of most types of foodborne illnesses. To ensure that staff members conform to personal hygiene requirements two issues must be considered, namely, the environment within which the staff must work and the quality of the staff members. From a food hygiene point of view the quality of the working environment depends on the facilities or equipment provided, which include toilets and protective clothing. The quality of staff depends upon their health, their hygiene and their habits (Johns, 1991).

According to Johns (1991) personal hygiene can be defined as follows: "as clean as is reasonably practical of hands, forearms, neck, hair and any clothing liable to come into contact with food." Thus, the aim of the study was to assess the knowledge, attitudes, beliefs and practices of the food handlers regarding personal and general hygiene, to assess the level and quality of training, and finally ascertain the involvement of management in training, and in personal and general hygiene. The results from the study will be used to give feedback to management, in order to effectively implement and maintain personal and general hygiene practices. Furthermore the results of this study might be used by other meat processing plants to compare or optimise their personal and general practices

2. MATERIALS AND METHODS

QUESTIONNAIRE DESIGN

A questionnaire (appendix A) was compiled consisting of two sections designed to acquire the relevant information from the respondents. The structured interview was the method of choice because 1) the interviewer had to follow a well-defined structure, preventing the respondent from own interpretation of the question, 2) it would allow more control over the interview process and people with no or low literacy levels could be interviewed, and 3) it would allow the interviewer to explain questions if unclear to the respondent (Czaja and Blair, 1996; Katzenellenbogen *et al.*, 1997).

Both closed and open-ended questions were used in the questionnaire (Coggon, 1995; Sapsford and Jupp, 1996) and questions were put in a simple, concise and specific manner to prevent ambiguity (Katzenellenbogen *et al.*, 1997). Care was also taken not to lead the respondents in answering the questions in a specific manner (Varkevisser *et al.*, 1995). A total of 37 questions were included in the questionnaire which was constructed in English, but during the interviews the interviewers translated the questions into the preferred language of the respondent, which included: English, Afrikaans, Zulu, Xhosa, South Sotho and Tswana.

DURING THE INTERVIEW

Prior to the interviews, arrangements were made with the management of the abattoir and the deboning room to obtain approval to interview employees, and also to utilise their facilities during the interviews. The respondents were interviewed during working hours at the deboning room and all twenty-eight workers working in the deboning area were selected. Before the interviewer commenced with the questions, he/she introduced him-/herself to the respondent and explained the purpose of the questionnaire and assured the respondent that the information would be handled confidentially. The interviewer also ensured that the respondent understood the objectives and importance of the study (Czaja and Blair, 1996). Each interview took ± twenty minutes (Figure 1).

DATA ANALYSIS OF COMPLETED QUESTIONNAIRES

The questionnaire was pre-coded and a code list was subsequently drawn up. The questionnaires were then analysed by hand using the code list and a data capturing sheet (Varkevisser *et al.*, 1995; Katzenellenbogen *et al.*, 1997). Finally, the data was presented in table format using frequencies and percentages.

Figure 1. During an interview regarding the personal and general hygiene practices of the meat handlers.

3. RESULTS AND DISCUSSION

EMPLOYMENT STATUS OF THE MEAT HANDLERS

The respondents comprised of two groups, including permanent and temporary staff. "Permanent staff" refers to staff who are permanently employed at the abattoir, while "temporary staff" refers to staff working on a contract basis (six months contract). Twelve respondents (42.9%) were employed on a permanent basis whilst sixteen respondents (57.14%) were temporary staff members.

PERSONAL HYGIENE

Practices regarding the washing of hands

The human body is a reservoir for numerous micro-organisms, with hands being the main agents for cross-contamination within a food handling establishment (Gordon-Davis, 1998). Jay (1996) further reports that the hands of food handlers generally reflect the environment and also the habits of an individual.

In Table 1, all the respondents indicated that they always wash their hands before entering the deboning room. Legislation specifies that no person will be allowed to handle food if the hands of such a person are not washed (Republic of South Africa, 1999). In addition to the frequency, the procedure of hand-washing is also considered important. Upon asking the respondents what they used for hand-washing, 92.9% indicated that they used hot water and soap, while 7.1% indicated that they used cold water and soap. Because hands are rarely free from micro-organisms (especially the bacteria *Staphylococcus aureus*) it is of the utmost importance that soap (preferably in a dispenser) and hot running water are used for this purpose, thus aiming to reduce the microbiological load on hands (Desmarchelier *et al.*, 1999).

Table 1. Practices of meat handlers regarding hand washing during the deboning process.

	Frequency (n)[a]	Percentage (%)
Frequency		
Always	28	100
Means of hand-washing		
Hot water and soap	26	92.9
Cold water and soap	2	7.1
Availability of soap		
Always	26	92.9
Most of the time	2	7.1
Hand-drying		
Disposable paper towels	28	100

[a] The sub-categories were occasionally only answered by selected respondents and may not always include all 28 respondents. In cases where less than 28 respondents responded, exact amounts (n) are indicated in brackets.

To ensure that the meat handlers wash their hands with hot water and soap, Van Zyl (1995) suggested that soap and hot water, at 45°C, should always be available at the washing-basins. Regarding the availability of soap, 92.9% of the respondents indicated that soap was always available, while 7.1% reported that soap was available most of the time (Table 1). In a study done by Desmarchelier *et al.* (1999) hand washing alone has no effect on *S. aureus* counts on hands and continued that the reduction of bacteria on hands depends on the mechanical action, the duration and the type of soap and sanitisers being used.

The final step in hand-washing is drying. All the respondents indicated that they used disposable paper towels for this purpose. The usage of disposable paper towels is recommended due to its single use followed by disposal, which eliminates the possibility of cross-contamination (Hobbs and Roberts, 1993). It is stipulated that all wash-basins shall, at all times, be provided with an adequate supply of soap, together with disposable paper towels (Republic of South Africa, 2000).

Practices regarding protective clothing

Without exception workers reported that they wore overalls, hairnets, hardhats and gumboots. Van Zyl (1995) proposed that the overalls, hairnets (beardnets if applicable), hardhats, gumboots and aprons (Table 2) should at all times be worn by meat handlers.

Because the purpose of wearing overalls is to protect both the food product and the meat handler from cross-contamination, overalls should be suitable to wear over other clothing (CFIA, 1990). The purpose of hairnets and beardnets is twofold: to prevent loose hairs and dandruff from falling into the food (primarily

Table 2. Information regarding the wearing and cleanliness of protective clothing.

	Frequency (n)	Percentage (%)
Protective clothing		
Overalls	28	100
Aprons	27	94.6
Hairnets	28	100
Beardnets (excluding female workers)	18	64.3
Hardhats	28	100
Gumboots	28	100
Stainless steel mesh gloves	24	85.7
Stainless steel apron	2	7.1
Cleanliness of protective clothing		
Washing of overalls		
Daily	27	96.4
Twice a week	1	3.6
Cleaning of gumboots		
Never	1	3.6
Always	27	96.4
Stainless steel mesh gloves (sterilisation)		
Not applicable (do not wear gloves)	4	14.3
After breaks	11	39.3
Daily	2	7.1
Visibly dirty or whenever there is a need	11	39.3

because hair is a possible source of *S. aureus*), and also to discourage the workers from running their fingers through their hair or scratching their scalps (Educational Foundation, 1992; Pelzcar *et al.*, 1993). All the respondents indicated that they wore hairnets, while 64.3% of the workers who had beards wore beardnets.

Although hardhats are also regarded as protective clothing, they fulfill a safety function (prevention of head injuries) rather than a hygiene function. All the respondents reported that they wore hardhats. In addition to protective clothing fulfilling a safety function, 85.7% wore stainless steel mesh gloves, while 7.1% wore stainless steel aprons underneath their clothing. The stainless steel gloves are to protect the worker from hand injuries, whilst the stainless steel apron protects the worker from injuries to the body, especially the stomach.

The emphasis with regard to protective clothing should not only be on protection, but also on cleanliness. Twenty-seven of the respondents reported that they put on protective clothing on a daily basis. One respondent, a temporary staff member, indicated that he puts on clean protective clothing twice a week, which gave an indication of the level of the supervision over the workers. According to Table 2 all the respondents indicated that they wore gumboots. Clean gumboots are just as important as clean overalls, because they may also be a source of contamination. Gumboots should therefore be washed at the facility provided, before entering the deboning room. The facility provided for the washing of the gumboots (Figure 2) consisted of washing-basins supplied with hot and cold water, liquid soap and a brush (Van Zyl, 1995). Only one respondent (3.6%) indicated that he never washed his gumboots. The stainless steel gloves also necessitate cleaning and sterilisation, but these gloves are difficult to clean, due to their woven construction (Van Zyl, 1998). Upon asking the respondents about the frequency of cleaning (water must be at 80°C for sterilisation) 39.3% reported that they sterilised their gloves after breaks.

Figure 1. The meat handlers washing their hands and gumboots at the facility provided before entering the deboning room.

Furthermore, a small percentage, 7.1%, sterilised their gloves on a daily basis while 39.3% sterilised their gloves whenever they were visibly dirty (usually full of fatty or bloody deposits). According to CFIA (1990) these gloves should be sterilised at regular intervals throughout the working shifts to prevent cross-contamination between the gloves and the meat. They should especially be sterilised when a source of contamination, such as an abscess, was cut open during the deboning process. Gill and McGinnis (2000) and Gill and Jones (1999) report that protective clothing such as the stainless steel mesh gloves harbour large persisting populations of bacteria. In a study done by Gill and Jones (1999), total aerobic counts were recovered from all samples with a log mean of about 9.2 colony forming units (cfu) per stainless steel mesh glove. Coliforms were recovered from about half of the stainless steel mesh gloves at log numbers of about 7.6 cfu per glove. *E. coli* however were only recovered from 2 out of the 25 stainless steel mesh gloves (Gill and Jones, 1999).

The practices and beliefs of the meat handlers regarding the reporting of illness

Because meat handlers are probable sources of contamination from micro-organisms, it is important that all possible measures be taken to reduce or eliminate such contamination (Mortimore and Wallace, 1994). One of the measures is to report illnesses to the supervisor or to management.

In Table 3, 96.4% of the respondents indicated that they reported illness to management and only one respondent reported that he did not report illness to management. Tricket (1997) suggests that whenever a food handler experiences diarrhoea, sore throat, fever, cold or open skin lesions, he/she should be obliged to report the condition to the supervisor or to management. All the respondents who indicated that they had reported illness, also reported that whenever they reported an illness to management, they were sent for

Table 3. The practices regarding the reporting of illness

	Frequency (n)	Percentage (%)
Report illness		
Yes	27	96.4
Other	1	3.6
Action of management		
Medical examination	27	96.4
Other	1	3.6
Medical examinations		
Yes	8	28.6
No need	20	71.4
Frequency of medical examinations (if yes) (n=8)		
Once a month	2	25
Annually	3	37.5
Before employment	3	37.5

medical examination by the local on-site nurse. Hobbs and Roberts (1993) emphasise the importance and advantages of having on-site health services especially in large food handling establishments, with a large work force.

According to Jacob (1989) routine medical examinations of food handlers are of little value because they merely reveals the health status of the worker at a specific point in time. He further states that these medical examinations are unreliable and that carriers of pathogens are unlikely to transmit these organisms. Only 28% of the respondents indicated that they went for routine medical examinations, while 71.4% indicated the opposite because they felt healthy and did not see the need to undergo medical examinations. Of the meat handlers who indicated that they underwent routine medical examinations, 25% underwent medical examinations once a month while 37.5% indicated that they underwent medical examinations either annually or on a once-off basis before employment (Table 3). Ziady *et al.* (1997) explained that food handlers must undergo medical examinations before employment to assess the general health of the food handler. However, Jacob (1989) suggests that routine medical examinations are seen as not being cost-effective and, in fact, unreliable.

The practices, attitudes and beliefs of the meat handlers regarding prohibited habits and actions inside the deboning room

In addition to the reporting of illness as a preventative measure of foodborne disease, regulations that prohibit smoking, eating and the wearing of jewellery are also regarded as preventative measures. All the respondents indicated (Table 4) that they did not eat or smoke inside the deboning room. Furthermore all the respondents indicated that they did not wear jewellery when they were handling the meat. Smoking inside the deboning room or whenever food is handled is prohibited, because whenever a cigarette is handled, the fingers come into contact with the lips and the saliva of the food together with micro-

Table 4. Information regarding prohibited habits and actions of the meat handlers

	Frequency (n)	Percentage (%)
Smoking		
Yes	0	0
No	28	100
Eating and drinking		
Yes	0	0
No	28	100
Jewellery		
Yes	0	0
No	28	100

organisms may consequently be transferred from the hands to the food (Burton, 1996). Furthermore smoking may also cause coughing, thus transferring aerosols containing micro-organisms to the food (Gordon-Davis, 1998). Eating is also prohibited inside the deboning room and this activity should be confined to a designated room (CFIA,1990). Jewellery is also a potential source of micro-organisms, because the skin under the jewellery provides a favourable habitat for these micro-organisms to grow (Tricket, 1997).

Information regarding the training of the meat handlers on personal hygiene practices

Table 5 represents information regarding the training of the food handlers on issues relating to personal hygiene. Fifty percent of the respondents indicated that they had received training in personal hygiene while the remaining 50% indicated that they had not received training. It was surprising that 57.1% of the respondents who indicated that they hadn't received training were permanent staff members, because it was expected that all permanent staff would have received training. The staff members who indicated that they had received training reported that 64.3% had received training from other meat handlers, whilst 14.3% had received training from videos and slides, as well as from the supervisor. A further 7.1% had received training from the local nurse. 21.4% of the respondents reported that, although they had received training, the training was not effective, whilst 78.6% indicated that the training received had indeed been effective. The 21.4% of the respondents who indicated that the training was ineffective, suggested that more training was needed (Table 5).

Training and education of food handlers on basic concepts and requirements of personal hygiene plays an integral part in ensuring a safe product for the consumer (Adams and Moss, 1997). To ensure this, there should be some form of induction training with regular updating and refresher courses for the food

Table 5. Information regarding the training of the meat handlers

	Frequency (n)	Percentage (%)
Receiving training		
Yes	14	50
No	14	50
Source (if yes) (n=14)		
Another staff member	9	64.3
Video's and slides	2	14.3
Clinic sister	1	7.1
Supervisor	2	14.3
Effectiveness (n=14)		
Yes	11	78
No	3	21.4

handlers. Meat handlers should furthermore understand the risks associated with contamination of food by microbiological agents, and should be trained to avoid the contamination of the meat. A formal employee training and assistance program (EAP) that describes all the training activities should be made attractive to the food handlers (CFIA, 1990). Ryser and Marth (1991) conclude that the training and education should be directed towards a thorough understanding of food hygiene, which includes sanitation.

According to Van Zyl (1995) worker to worker training is affecting the level of education of the meat handlers. This author explains that most of the time management leaves the training of new workers to more experienced workers who themselves often fail to realise the importance of personal hygiene. Therefore supervision is important to ensure that all the workers practise a high level of personal hygiene.

Practices regarding the supervision of the meat handlers on personal hygiene

The information regarding supervision over personal hygiene is shown in Table 6. All the respondents indicated that there was supervision regarding personal hygiene throughout the day. Management should ensure that there is control over the meat handlers, especially in the case of obvious signs of disease and where there are workers who do not comply with the specified requirements. The supervision of the workers should be the task of an appointed supervisor (CFIA, 1990).

In addition to formal supervision, mechanisms like warnings and fines should be put in place to ensure that workers conform to the requirements. Warnings should be given if the worker does not comply with the requirements. In this study 53.6% of the respondents indicated that they had received warnings, while

Table 6. Information regarding managerial supervision over personal hygiene

	Frequency (n)	Percentage (%)
Supervision		
Yes	28	100
Frequency		
Throughout the process	28	100
Disciplinary actions		
Warnings	15	53.6
Fines	13	46.4

46.4% indicated that they had received fines when they did not comply with the requirements (Table 6).

GENERAL HYGIENE

Practices regarding the disinfection of equipment

The adequacy of a cleaning program is judged on the basis of the adherence to specified Standard Operating Procedures (SOPs) during the cleaning and disinfection process and the inspection of cleaned facilities and equipment (Gill *et al.*, 1999). This authors further report that improperly cleaned equipment has been implicated in previous reported outbreaks of foodborne diseases, it is therefore apparent that cleaning and disinfecting processes should fully comply with regulations. Gill and McGinnis (2000) report that a primary source of *E. coli* deposited on meat during the deboning process appears to be the detritus in equipment which was not removed during daily cleaning. In addition Samelis and Metaxopoulos (1999) report that the processing environment are more implicated as a source of *Listeria monocytogenes* than live animals or carcasses and should therefore receive special attention during cleaning and disinfection. The absence of *L. monocytogenes* after cleaning and disinfection is indicative of an effective cleaning and disinfection program.

Regarding the frequency of cleaning and disinfection in this study, only one respondent indicated that he never disinfected his knife, while 42,8% indicated that they cleaned and disinfected their knives after breaks and during shifts (Table 7). Furthermore 25% of the respondents reported that they only disinfected their knives during shifts, while 10.7% indicated that they disinfected their knifes only after breaks. The remaining 17.9% indicated that they disinfected their knives whenever they were excessively and visibly soiled with fat or blood.

Table 7. Information regarding the cleaning and disinfection of the equipment and surfaces

	Frequency (n)	Percentage (%)
Frequency		
Knives and hooks		
Never	1	3.6
Only after breaks	3	10.7
Only during shifts	7	25
During breaks and shifts	12	42.8
Excessively soiled	5	17.9
Surfaces		
Before commencing with work	22	78.6
Between shifts	1	3.6
During shifts	4	14.2
Weekly	1	3.6
Means of disinfection		
Hot running water	2	7.1
Hot running water and detergent	25	89.3
Cold water and detergent	1	3.6

The respondents were also questioned on the frequency of cleaning and disinfection of the working surfaces such as the tables and conveyor belt. A percentage of 78.6 reported that the surfaces were cleaned and disinfected before the commencement of work each day. Furthermore only 3.6% indicated that the surfaces were being cleaned and disinfected between shifts, while 14.2% indicated that the surfaces were being cleaned and disinfected during shifts. One respondent indicated that the surfaces were cleaned and disinfected on a weekly basis (Table 7).

The products and procedures applied to clean and disinfect the equipment are just as important as the frequency of cleaning and disinfection. Upon questioning the respondents regarding the procedures of cleaning and disinfection, a markedly high percentage of 89.3% of respondents indicated that hot running water and detergent were used to clean and disinfect the surfaces. A small percentage, 3.6%, indicated that cold running water and detergent were being used to disinfect the surfaces. Two respondents (7.1%) reported however that hot water only was used to clean and disinfect the surfaces.

Because meat is exposed to contamination during slaughtering and handling, proper sanitation plays a major role in ensuring the delivery of a microbiologically safe product with a long shelf life to the consumer (Gill, 1996). Lawrie (1998) also points out unhygienic knives and surfaces as sources of contamination, which may lead not only to food spoilage but also to food poisoning. According to Van Zyl (1995) and Gill and Jones (1999) knives and surfaces should be cleaned and disinfected throughout the day; however, if this were not possible, then they should at least be cleaned and disinfected at the end of each working day. The detritus that persists on the equipment after inadequate cleaning and disinfection are particularly a source of *E. coli* (Gill and Jones, 1999).

The products used for cleaning and disinfection are just as important as the frequency of treatment, thus the proper detergent should be used that suits the equipment, and the process, and which has been approved by the appropriate authorities (Educational Foundation, 1992). In addition, the effectiveness of a detergent depends on its concentration, the temperature, the contact time of the detergent and the presence of organic matter on the surfaces (Gracey, 1986). Hot water under pressure in conjunction with a suitable detergent should be used during cleaning and disinfection in any room of an abattoir where meat or animal products are handled or processed (Republic of South Africa, 2000).

The level of contamination and effectiveness of the inspection procedure on the slaughtering floor regarding the incoming carcasses for deboning

Table 8 shows the information obtained regarding the contamination of incoming carcasses that were ready to be deboned. Not all the respondents responded to these questions, which depended upon where they were working on the line inside the deboning room. Of the respondents (n=25), 84% indicated that the carcasses were visibly clean. The other 16% indicated that the carcasses in general were not visibly clean when entering the deboning room. This 16% of the respondents indicated that the carcasses were contaminated with faecal material, hair, grease and even building material such as dry paint.

The respondents were also questioned on the frequency at which they encountered abscesses and Cysticercosis (measles). 21% reported that they encountered abscesses on a weekly basis, while 73.7% indicated that they encountered abscesses on a monthly basis. One respondent (5.3%) indicated that he encountered abscesses annually. Nine (42.9%) respondents indicated that they encountered measles on a weekly basis, while 57.1% encountered measles on a monthly basis.

Table 8. Information regarding the incoming carcasses ready to be deboned

	Frequency (n)	Percentage (%)
Visible cleanliness (n=25)		
Yes	21	84
No	4	16
Presence and frequency		
Abscesses (n=19)		
Weekly	4	21
Monthly	14	73.7
Annually	1	5.3
Measles (n=7)		
Weekly	3	42.9
Monthly	4	57.1
Faecal (n=4)		
Daily	1	25
Weekly	2	50
Monthly	1	25
Hair and skin (n=10)		
Daily	1	10
Weekly	5	50
Monthly	4	40
Soil and grease (n=7)		
Daily	2	28.6
Weekly	4	57.1
Monthly	1	14.3
Action upon encountering Above (n=23)		
Notify management	12	52.2
Remove/trim	11	47.8

Of the respondents who indicated that they had encountered faecal, hair, skin, soil and grease contamination, one (25%) respondent had encountered faecalcontamination on a daily basis, while 2 respondents (50%) indicated that they encountered faecal contamination on a weekly basis. One respondent (25%) indicated that he encountered faecal contamination on a monthly basis. Furthermore, one respondent (10%) indicated that he encountered hair and skin on a daily basis, while five respondents (50%) indicated that they encountered hair and skin on a weekly basis, and four respondents (40%) indicated that they encountered hair and skin on a monthly basis. Respondents indicating that they had encountered soil and grease, indicated that 28.6% encountered soil and grease on a daily basis, with a larger percentage of 57.1% indicating that they encountered soil and grease on a weekly basis. A smaller percentage (14.3%) reported that they encountered soil and grease on a monthly basis (Table 8). This indirectly gives an indication of the effectiveness or rather ineffectiveness of the inspection procedure during slaughtering.

The respondents were also questioned regarding the action they took whenever they encountered the abovementioned conditions. Twelve (52.2%) respondents indicated that they notified management, while eleven (47.8%) indicated that they removed or trimmed off the affected or contaminated areas. Aberle *et al.* (2001) report that one of the major sources of carcass contamination is the live animal itself. According to Nottingham (1982) the hides, skins, faecal material and soil are the major sources of micro-organisms. In one particular study done, counts of 10^5 per cm^{-2} were found to be common on the hides of cattle (Hayes, 1985). Therefore it is of the utmost importance that hygienic practices be employed in an abattoir during slaughtering to ensure that bacterial counts are kept as low as possible, because most of the meat will undergo further processing which may include deboning (Lawrie, 1998).

Because hair and skin are possible sources of *B. cereus* and *S. aureus*, the presence of hair and skin on the meat is an indication of poor inspection standards (Lawrie, 1998; Forsythe, 2000). In addition abscesses, also contain very high numbers of pathogenic organisms that include *S. aureus*. Thus, whenever meat is found to contain abscesses it should be rejected (Church and Wood, 1992). Faecal material, which is a source of *E. coli* and *Salmonella* spp. present on meat, is an indication of poor slaughtering techniques. Therefore, according to the Committee on the Scientific Basis of the Nation's Meat and Poultry program (1995), faecal contamination of meat during slaughtering is considered the single most important aspect to be kept in mind during sanitary slaughtering and dressing. It is therefore important to notify the supervisor whenever abovementioned conditions are encountered.

Training of meat handlers on general hygiene practices

Industrial training may be defined as the art of helping employees to acquire desirable habits necessary for the performance of their tasks (Longrée and Blaker, 1982). Sanitation-conscious workers do not just happen, they must be developed through the provision of continuous training to develop safe food handling and sanitation habits.

Thirteen (46.4%) of the respondents indicated that they had received training in general hygiene, while 53.6% indicated that they had not received training. These results may imply that the food handlers are not being assisted to acquire desirable habits while working, because a large percentage of workers indicated that they had not received training. Thus it seems that sanitation-conscious workers are not being developed. If food handlers are properly educated on the practical aspects of food microbiology and the basic principles of cleaning and disinfection, a decrease in foodborne disease outbreaks will be a definite outcome (Martínez-Tomé *et al.*, 2000).

GENERAL DISCUSSION AND OBSERVATIONS OF THE DEBONING ROOM

From the results obtained it is evident that there are problems regarding communication and supervision between the workers and management. The fact that, for each question, similar profiles were obtained, for example: a large percentage reported washing their hands with hot water and soap, and a smaller percentage with cold water and soap; a large percentage suggested that soap was always available, with a smaller percentage saying that it was available most of the time. It is quite possible that workers may have responded to the questions in the way that they perceived as wanted. In addition it was also observed that the workers were weary of the supervisor and may also have answered a question in a specific manner to avoid an incident with the supervisor. This was notwithstanding the fact that the anonymity of the workers were guaranteed.

The results furthermore indicated that problems exist regarding the reporting of illness. A large percentage indicated that they are of the opinion that it was not necessary to report for regular medical examinations, while a smaller percentage felt that it was necessary to undergo medical examinations. The reported frequencies regarding the undergoing of medical examinations also vary considerably, with some workers going once a month, while others only go annually or before commencing employment.

Moreover, the results also indicate that there might be problems pertaining to the training of the workers. An equal percentage of workers indicated that they had received or had not received training; they also indicated various sources of training. The large percentage indicating that the training was effective may be due to the respondent answering in the expected way, for fear for disciplinary actions against him/her.

The cleaning and disinfection of equipment are not uniform, because not all the workers are cleaning and disinfecting their equipment at the same intervals. The same situation is true for the cleaning and disinfection of surfaces, and the means of cleaning and disinfection also vary from respondent to respondent. This implies that the workers are not educated nor monitored regarding the general sanitation of the deboning room.

4. CONCLUSION

This study has attempted to provide an overview on the personal and general hygiene of the meat handlers of the deboning room of a South African red meat abattoir. The results indicated that there are some personal and general hygiene measures in place and that the workers adhere to the majority of them. However, the workers indicated that there is a need for more effective training in both personal and general hygiene practices. This also served to indicate that the workers have a positive attitude towards personal and general hygiene. Some recommendations may be made on the basis of the information obtained from this survey.

Without exception staff complying with the necessary requirements, should be hired. This includes qualifications or appropriate experience, and if this is not possible, then the staff should undergo the necessary training to meet with the requirements. Management must strive to establish employee commitment regarding personal and general hygiene to ensure safe meat from the deboning room to the consumer. Furthermore, continuous supervision over personal and general hygiene practices of the staff, by the supervisor or manager, is of the utmost importance in ensuring that staff conforms to the requirements and that healthy staff members are handling the meat throughout the deboning process.

Worker to worker training should be prohibited at all times and only a competent and educated person should be allowed to train the staff. Such a person should be responsible for training both new staff and also the permanent staff members. This will consequently result in uniformity regarding training. Moreover, a cleaning schedule for the deboning room should be drawn up and its importance impressed upon the staff. Staff should furthermore be informed about each staff member's responsibility and the importance of adhering to the cleaning schedule at all times. Formal rules that ensure safe food handling practices and prohibit unsafe personal habits may additionally be drawn up. This will enable the supervisor to correct any deviations from the rules.

In addition to establish the above the supervisor and manager must set an example by always following the employee rules themselves, because if management is not taking personal and general hygiene seriously, then the staff members will not do so either (Educational Foundation, 1992). High intention, sincere effort, intelligent direction and skilful execution should be part-and-parcel of the repertoire of both management and workers in order to function optimally to ensure a microbiological safe product to the consumer.

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CHAPTER 3

BACTERIAL POPULATIONS ASSOCIATED WITH MEAT FROM THE DEBONING ROOM OF A GRADE A RED MEAT ABATTOIR

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BACTERIAL POPULATIONS ASSOCIATED WITH MEAT FROM THE DEBONING ROOM OF A GRADE A RED MEAT ABATTOIR

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ABSTRACT

In highly perishable foodstuffs such as fresh red meat the threat of food poisoning is particularly great. In this study red meat samples were collected from a deboning room of a grade A abattoir. The samples were analysed for the presence of *Bacillus cereus, Staphylococcus aureus, Pseudomonas* spp., *Listeria monocytogenes, Escherichia coli* and *Salmonella* spp. The aerobic plate counts as well as *Enterobacteriaceae* were also enumerated. Almost without exception the counts exceeded the microbiological guidelines for raw meat as proposed by the South African Department of Health. The average *Bacillus cereus* count over the sampling period was 8.32×10^3 cfu.g^{-1}, for *Staphylococcus aureus* and *Pseudomonas* spp. 1.72×10^5 cfu.g^{-1} and 1.7×10^5 cfu.g^{-1} respectively and for *Escherichia coli* 3.4×10^5 cfu.g^{-1}. Sixty percent of the samples were positive for presumptive *Salmonella* spp. while 52% of the samples tested positive for the presence of *Listeria monocytogenes*. The aerobic plate and *Enterobacteriaceae* counts were 1.7×10^7 cfu.g^{-1} and 4.6×10^6 cfu.g^{-1} respectively. The inter-relationships between the micro-organisms were also determined, and a strong correlation between the aerobic plate counts and *Enterobacteriaceae*,

Pseudomonas spp. and *Staphylococcus aureus* respectively, was noted. The data highlighted the need, especially in developing countries, for a more systematic approach to ensuring safe food through implementing quality control methods to prevent the entry and proliferation of pathogens in meat and meat products, especially during processes with a high degree of handling, such as deboning.

1. INTRODUCTION

Deboning is the process whereby meat is removed from the skeletal bones and cut into retail cuts such as loin, rump or sirloin, whilst the bones are used for by-products such as bone-meal (Van Zyl, 1995). In South Africa, abattoirs are classified into grades that are determined by the daily throughput of slaughter animals, with a grade A abattoir having the largest throughput of more than one hundred slaughtering units per day. Grade E abattoirs, on the other hand, have the smallest throughput of one to eight slaughtering units a day (Van Zyl, 1998). Many of the high throughput abattoirs have on-site deboning facilities where they produce retail cuts for distribution to the retail markets. During the deboning process the meat undergoes extensive handling and is exposed to surfaces that are more susceptible to contamination. However, the extent of contamination is dependent upon the local environment, the throughput of meat, the temperature and the cleanliness of utensils such as the cutting tables, conveyor belt and knives (Eisel *et al.,* 1997, Gill and Jones, 1999).

During the deboning process the different retail cuts are removed from the hanging carcass, placed on stainless steel tables and manually trimmed to remove excess fat. The meat is then placed on a conveyor belt that transports it to another room where it is vacuum-packaged and boxed. The final step includes two different handling procedures. The first involves the transportation of the freshly boxed meat directly to the dispatch area from where it is transported in a temperature controlled truck (temperature not exceeding 5-10°C), to the retail market. The second handling procedure is the freezing of the boxed meat at –5 to –10°C. The frozen meat is then dispatched at a later stage as demanded by the retail markets.

Aberle *et al.* (2001) explain that most of the contamination problems experienced might be overcome with vacuum-packaging and they point out that the low levels of oxygen that are trapped in or on the meat will be used by the micro-organisms and will result in metmyogloblin formation. These activities consequently result in carbon dioxide production and pH reduction whilst facultative anaerobic bacteria may thrive in these conditions and produce lactic acid. The consequent bacterial growth is inhibited by the low pH and oxygen absence, significantly extending the shelf life of the vacuum-packed meat. However, in the case of heavily contaminated meat it might undergo pigment decomposition, discolouration and development of off-odours resulting from the growth of certain anaerobic bacteria (Gill, 1996).

Potential spoilage bacteria and pathogens generally associated with red meat include *Bacillus cereus, Staphylococcus aureus, Pseudomonas* spp., *Listeria monocytogenes, Escherichia coli* and *Salmonella* spp. (Eisel *et al.*, 1997; Forsythe, 2000). Elevated numbers of these organisms have been said to be indicative of food-related illness. Lower numbers, on the other hand, would present useful information on system contamination and the extent of downstream processing steps. For example, possible process and heat resistant spore- and toxin-producing bacteria such as *B. cereus* and *S. aureus*, when present in fresh meat samples, will necessitate comprehensive heat treatment during downstream processing prior to consumption (Vorster *et al.*, 1994; Notermans *et al.*, 1997). Elevated *Pseudomonas* spp. and *L. monocytogenes* numbers, however, might pose spoilage problems when considering their ability to proliferate at moderate to low temperatures (Gill, 1996; Samelis and Metaxopoulos, 1999).

During the previous decade an increasing number of reports emphasised the inadequacy of traditional *ante*- and *postmortem* routine inspections on red meat carcasses whilst assessing food safety (Hathaway, 1993). This shortcoming, condemned by regulatory authorities and concerned consumers, increased the demand within the red meat industry for the application of systematic approaches in the assessment of microbiological hazards (Berends *et al.*, 1997).

It was therefore the purpose of this study to firstly quantify the potential spoilage bacteria and pathogens on meat from the deboning room of a grade A abattoir and to compare these results with proposed guidelines, and secondly, to determine the correlation amongst the various micro-organisms. Possible interactions amongst the various microbial groups during the processing stages were finally investigated as well as possibilities to determine whether selected organisms could be used as indicators of pathogens that are difficult to analyse, such as *Salmonella* spp. and *L. monocytogenes*.

2. MATERIALS AND METHODS

Sampling site

Samples were collected from the deboning room of a grade A abattoir, situated in the Free State Province, central South Africa.

Sampling protocol

Between September and December a total of 50 meat samples were collected at two week intervals. On each sampling day samples were collected randomly every 15 minutes over a period of 150 minutes (± 10 samples per interval). The samples were aseptically collected from the meat on the conveyor belt, immediately before vacuum-packaging and stored on ice in sterile Whirl-Pak bags (Nasco, USA) until analysis. The samples were analysed for the presence of *B. cereus, S. aureus, Pseudomonas* spp., *L. monocytogones, E. coli,* presumptive *Salmonella* spp. as well as for total plate and *Enterobacteriaceae* counts.

Sample treatment

Ten gram portions of the samples were aseptically homogenised in a Seward Stomacher 400 for 2 minutes (Nortjé *et al.*, 1999), in 90 ml sterile peptone water (Biolab, Midrand, SA). Serial dilutions were aseptically prepared and plated onto various basal, selective and differential media. All plates were incubated under aerobic conditions. After incubation the colonies were enumerated by means of a colony counter (Gerber Instruments AG, Effretikon, Switzerland).

Identification of bacteria

Aerobic plate counts and *Enterobacteriaceae*

For the enumeration of aerobic plate counts, Plate Count Agar (PCA) plates (Biolab) were incubated at 25°C for 3 days (Vorster *et al.*, 1994), whilst for *Enterobacteriaceae* Violet Red Bile Glucose Agar (Oxoid, Basingstoke, UK) were incubated for 24 – 48 hours at 32°C. In the case of the latter, typical colonies were purple surrounded by purple haloes (Hayes, 1985).

Bacillus cereus

Bacillus cereus Selective Agar plates (Oxoid) were used for cultivation and enumeration. The plates were incubated at 30°C for 18 – 24 hours and examined for typical *B. cereus* colonies which were characterised by peacock blue colonies, with egg yolk precipitate (Nortjé *et al.*, 1999). Confirmation of colonies was done according to the procedure of Holbrook and Anderson (1980).

Staphylococcus aureus

Baird-Parker (Biolab) agar plates were incubated for 24 – 26 hours at 35°C. Typical *S. aureus* colonies (black colonies with white margins surrounded by clear zones) were enumerated. The colonies were confirmed using the coagulase test (Staphytect test kit, Oxoid).

Pseudomonas spp.

Cetrimide agar plates (Biolab) were incubated for 18 – 24 hours at 25°C. Typical *Pseudomonas* spp. colonies were fluorescent under ultra violet light (366 nm) and confirmed with oxidase sticks (Oxoid, Hayes, 1985).

Listeria monocytogenes

A method previously described by Lovett *et al.* (1987) that has been shown to recover an inoculum of less than 10 cfu.ml^{-1} was used in this study. Pre-enrichment was done in *Listeria* Enrichment Broth (Oxoid) for 7 days at 30°C followed by inoculation onto Oxford agar (Oxoid) which was incubated at 37°C for 48 hours. The colonies were confirmed with the biochemical CAMP test described by Forsythe (2000).

Escherichia coli

Violet Red Bile MUG agar plates (Biolab) were incubated at 37°C for 18 – 24 hours. Typical *E. coli* colonies were fluorescent blue under UV light (366 nm; Forsythe 2000).

Presumptive *Salmonella* spp.

The procedure of Hayes (1985) was selected for this study, presenting the results only as positive or negative (Van Schothorst and Renaud, 1983). Pre-enrichment was done in Buffered Peptone Water (Biolab) at 35°C for 16 - 20 hours followed by incubation in Rappaport-Vassiliadis Enrichment Broth (Oxoid) for 24 – 48 hours at 42°C. The broth was further subcultured on Brilliant Green Agar (Oxoid) and incubated for 18 – 24 hours at 35°C (Van Schothorst and Renaud, 1983). The colonies were confirmed using a rapid culture confirmation test kit for the presumptive identification of *Salmonella* (Microgen Bioproducts, Surrey, UK).

Statistical processing

Duplicate plates showing 30 – 300 colony forming units (cfu) were counted and the means determined. The bacterial counts were expressed as log cfu per gram ($cfu.g^{-1}$) of food. Level of significance was determined at the $P \leq 0,05$ level. Pearson's correlation was calculated statistically between the micro-organisms and summarised by means of a correlation matrix. The evaluation categories of Stockburger (1996) were used to evaluate the various correlations.

3. RESULTS AND DISCUSSION

Enterobacteriaceae and aerobic plate counts

The family *Enterobacteriaceae* include *E. coli*, *Shigella* spp., *Edwardsiella* spp., *Salmonella* spp., *Citrobacter* spp., *Klebsiella* spp., *Enterobacter* spp., *Serratia* spp., *Proteus* spp., *Morganella* spp., *Providencia* spp. and *Yersinia* spp. and therefore present a holistic view of the presence of these organisms on the product. Aerobic plate counts are, on the other hand, widely used to determine the general degree of microbial contamination (Aberle *et al.*, 2001). The results for *Enterobacteriaceae* obtained during this study are presented in Figure 1(A). *Enterobacteriaceae*, which are also indicative of possible faecal contamination, ranged from 2.1 x 10^4 and 1.5 x 10^7 cfu.g^{-1}. No significant differences were observed between the 5 sampling weeks. Aerobic plate counts presented in Figure 1 (B), ranged between 1.4 x 10^5 and 5.7 x 10^7 cfu.g^{-1}. Significant differences in the plate counts were however found between weeks 1 and 2 and between weeks 2 and 3. When observing the aerobic plate counts, the *Enterobacteriaceae* counts and *Pseudomonas* spp. counts the same tendency can be observed throughout the sampling period. Because these micro-organisms are indicative of the shelf life of the meat it may be deducted that the shelf life of the meat will be reduced because of the high levels in which these micro-organisms occur. The pathogenic micro-organisms (*B. cereus, S. aureus, E. coli, L. monocytogenes* and *Salmonella* spp.) did not necessarily show the same tendency throughout the sampling period.

Bacillus cereus

Because of the ubiquitous nature of this organism it was expected that it would be present on raw meat (Schultz and Smith, 1994). In a study done by Mosupye and Von Holy (2000), *B. cereus* was predominant in both raw and prepared foodstuffs. Its survival properties (endospores) and ability to produce

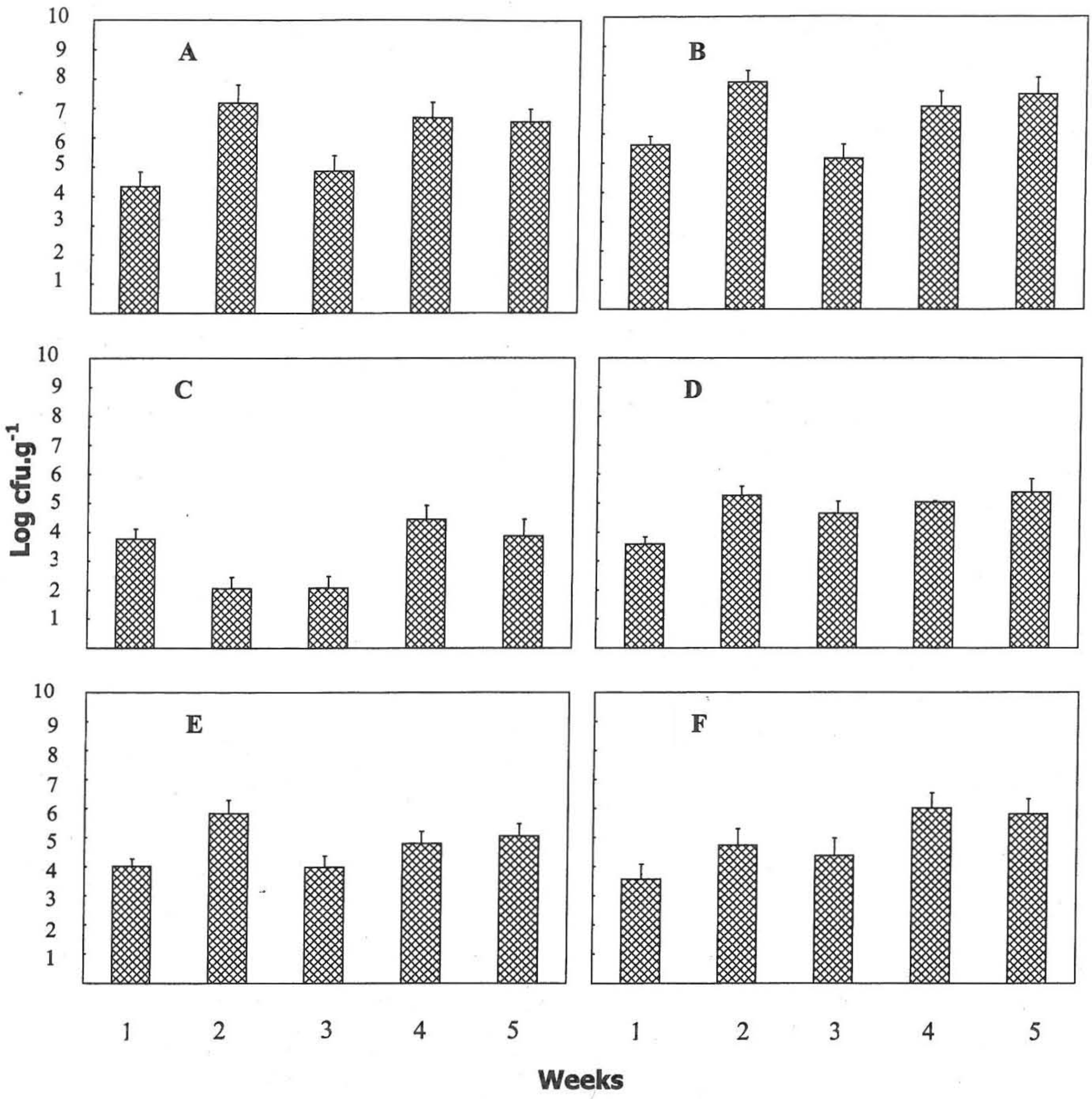

Figure 1. The incidence of micro-organisms over a 5 week period (n=50) associated with fresh beef from the deboning room of a grade A abattoir (A:aerobic plate counts; B: *Enterobacteriaceae*; C: *B. cereus*; D: *S. aureus*; E: *Pseudomonas* spp.; F: *E. coli*).

heat-stable toxins (associated with food poisoning) further labels *B. cereus* as a potential risk when present in food (Notermans *et al.*, 1997). During the slaughtering process the meat is exposed to sources of *B. cereus* which include soil, hides, equipment and also personnel (Lawrie, 1998). The level of *B. cereus* on meat from the deboning room is shown in Figure 1(C). The mean counts (n=50) over the five sampling weeks ranged between 1.15×10^2 and 2.81×10^4 cfu.g^{-1}. The South African Department of Health (2000) has proposed microbiological specifications to be used as guidelines, with 1000 cfu.g^1 as the maximum limit for *B. cereus* in raw meat. The infectious dose of *B. cereus* is estimated at 10^5 cfu.g^{-1} (Lattuada and McClain, 1998). Taking the above into consideration, the results showed that the *B. cereus* counts at sampling weeks one, four and five exceeded the proposed guideline but not the infectious dose. Likely sources of contamination include soil and hides of the animals. This was found to be the case especially when comparing these results with the results obtained from a questionnaire study (Nel *et al.*, 2003) at the same deboning room where 50% (n=5/10) of the respondents, who are employed at the receiving point of the carcasses, indicated that they encounter hair and skin on a weekly basis while 57.1% (n=4/7) indicated that they encounter soil on a weekly basis on the carcasses ready for deboning.

In studies done by Nortjè *et al.* (1999) and Mosupye and Von Holy (2000) the incidence of *B. cereus* is higher in cooked and processed meat than in raw meat samples. When comparing the counts of this study to the results of the above-mentioned ground beef samples the mean count (1.99 x 10 cfu.g^{-1}) is lower than the unprocessed retail cuts sampled in this study. The *B. cereus* levels in this study could further increase if exposed to handling and processing because this organism usually originates from environments such as surfaces or utensils applied during processing. Mosupye and Von Holy (2000) mentioned that its presence in meat, especially in such high levels, indicates a potential risk of producing heat stable toxins. When comparing the counts of the different weeks from this study it was found that there is a significant difference between week 1 and 2 and week 1 and 3. This could be due to the fact that the lowest levels of *B. cereus* were detected during these weeks. These differences in levels throughout the sampling period highlight the fact that there are problems regarding the consistency in microbial levels the abattoir. The ideal would be that the levels remain relatively low (to comply with legislation) and consistent on a day-to-day basis. This can be achieved through the effective implementation of knowledge and systems such as standard operating procedures (SOPs), good manufacturing practices (GMP) and hazard analysis critical control point (HACCP).

Staphylococcus aureus

The occurrence of *Staphylococcus aureus* on raw meat would be expected, because it is a principal component of the skin of humans and animals (Adams and Moss, 1997). The South African Department of Health (2000) has proposed a maximum limit of 100 cfu.g^{-1} for *S. aureus* with a level of 10^5 cfu.g^{-1} being indicative of food poisoning occurrence. Relatively high levels of *S. aureus* were present in the samples analysed and are shown in Figure 1(D), ranging from 3.8×10^3 to 2.42×10^5 cfu.g^{-1}. These levels exceed the maximum limit over the entire sampling period, with weeks two, four and five exceeding the standard suggesting a possible food poisoning hazard (Forsythe, 2000). No significant differences were observed between the different weeks except between week 1 and 2.

In a study done by Vorster *et al.* (1994) in South Africa on ground beef the mean *S. aureus* count was 2.5×10 cfu.g^{-1}. This count is much lower when compared to the results of this study, keeping in mind that the retail cuts is not yet processed, which may subsequently increase the levels of *S. aureus* in these meat samples to even higher levels. In another study done by Desmarchelier *et al.* (1999) the incidence of *S. aureus* ranged between 33%

(n=10/30), 60% (n=12/20) and 12.5% (n=5/40) for carcasses after overnight chilling at 3 different abattoirs compared to the 100% (n=50) incidence of *S. aureus* in this study. This high incidence of *S. aureus* in this study could be the result of frequent contamination during slaughtering, dressing and evisceration because Nel *et al.* (2003) found that 50% (n=5/10) of the respondents indicated that they encounter hair on the carcasses ready to be deboned, thus contaminated carcasses are entering the deboning room from the slaughtering floor. Therefore it could be deduced that the carcasses are more implicated as sources of *S. aureus* than the food handlers in the deboning room because of the personal hygiene practices applied. Desmarchelier *et al.* (1999) mentioned that such high incidences of *S. aureus* on beef samples is of particular concern because it may be a source of contamination to other foods and may present risk in processed foods (as mentioned earlier for ground beef), therefore it is essential to reduce the incidence of *S. aureus* on deboned retail cuts. Furthermore, if this high incidence of *S. aureus* is combined with temperature and storage abuse a definite possibility exists that consumers may become ill.

***Pseudomonas* spp.**

Pseudomonas spp. represents the largest genus of bacteria usually present in fresh foods and is therefore also expected to occur in meat (Gill, 1996; Buys *et al.*, 2000). Research has shown that *Pseudomonas* spp. predominate in fresh meat stored aerobically at chilled temperatures, thus indicating *Pseudomonas* spp. to be psychrophilic (Buys *et al.*, 2000; Aberle *et al.*, 2001). Figure 1(E) represents the incidence of *Pseudomonas* spp. on fresh meat derived from the deboning room. The counts of this study ranged from 9.6×10^3 to 6.6×10^5 $cfu.g^{-1}$ with no notable differences observed between the sampling weeks. Levels and composition of the *Pseudomonas* spp. population are often determined by the local environmental microflora of each abattoir, thus differing from abattoir to abattoir (Lawrie, 1998). Therefore

Notermans *et al.* (1994) report that *Pseudomonas* spp. can become indigenous to processing plants.

Because *Pseudomonas* spp. are the dominant spoilage organisms under aerobic conditions (Gill, 1996; Buys *et al.*, 2000), if the meat from this study were exposed to aerobic conditions *Pseudomonas* spp. would probably become the dominant spoilage organism, and if present in such high levels the shelf life of the meat could be decreased substantially. In contrast, if the meat are stored under anaerobic conditions which are the case in this study, the shelf life may be increased provided that the initial count of *Pseudomonas* spp. is low because anaerobic conditions may partially or totally inhibit the growth of *Pseudomonas spp.* (Gill and Jones, 1996). However, in research done by Lee and Yoon (2001) and Gill and Badoni, (2002) the *Pseudomonas* spp. levels in vacuum-packaged beef increased in the first few weeks of storage.

Escherichia coli

The *Escherichia coli* levels ranged from 3.7×10^3 to 1.0×10^6 cfu.g^{-1} (Figure 1(F) with no significant difference between the various sampling intervals. The maximum limit proposed by the South African Department of Health (2000) of 10 cfu.g^{-1} was exceeded over the whole sampling period. In a study done by Eisel *et al.* (1997) the average counts for *E. coli* on retail cuts were between 1 - 2 cfu.g^{-1} (product) and 1 – 2 cfu 100 cm^{-2} (surface), much lower when compared with this study. *E. coli* may be used as an indicator micro-organism because it provides an estimate of faecal contamination and poor sanitation during processing (Eisel *et al.*, 1997). It should be kept in mind that high levels of this organism could be indicative of exposure to faecal pollution originating from improper slaughtering techniques, contaminated surfaces and/or handling of the meat by infected food handlers. Nel *et al.* (2003) reported that a large percentage (50%) of the respondents indicated that they encounter faecal material on a weekly basis, while 25% (n=1/4) encounter faecal material on a daily and monthly basis respectively on incoming carcasses. This implies that the carcasses may be regarded as the principal source of *E. coli* when compared with the meat handlers and the processing environment. The levels found in this study were consistent with the findings of Gill *et al.* (1999) and Gill and McGinnis (2000) that the levels of *E. coli* increase progressively (counts increased up to 3 log units and more) during the different stages of carcass handling, especially during the deboning process. Therefore it is of the utmost importance that *E. coli* levels be kept as low as possible during slaughtering and deboning, through adhering to SOPs and GMPs during initial carcass handling such as the evisceration process where intestinal material (source of *E. coli*) may come into contact with the carcass.

Listeria monocytogenes

Madden *et al.* (2001) reports on studies done on beef carcasses in Northern Ireland, Britain, USA and Australia where *L. monocytogenes* were found to be absent, 7% positive, 4.1% positive and 15% positive respectively. The results obtained in this study however, showed that 52% (n=26/50) of the samples were positive for *L. monocytogenes* (Table 1). This high incidence of *L. monocytogenes* could be due to the fact that the environment where the meat is slaughtered and processed are more probable sources of the organism than the animals. According to Nel *et al.* (2003) inconsistency exists regarding the cleaning and disinfection of the deboning room and that the slaughtering practices practised on the slaughtering floor are not up to standard, supporting the high incidence of *L. monocytogenes* levels on the meat. This is consistent with a study done by Nesbakken *et al.* (1996) where the occurrence of *L. monocytogenes* in meat might originate mainly from the environment in which the meat is processed rather than the animals themselves. A possible reason for the high incidence could be the fact that the samples in the study of Madden *et al.* (2001) were collected from the carcasses prior to processing whilst the samples collected in this study were collected after deboning. Therefore the

Table 1. Percentage of samples tested positive for the presence of *L. monocytogenes* and presumptive *Salmonella* spp.

Micro-organism	Percentage (%)
L. monocytogenes	52
Presumptive Salmonella spp.	60

management of the abattoir and the deboning room must give special consideration to cleaning and disinfection in order to keep the *L. monocytogenes* levels as low as possible. Intervention must be directed towards the sources of the organism in order to ensure a product with low levels of contamination.

Gill *et al.* (1995) also mentions that *L. monocytogenes* is an appropriate indicator for the behaviour of cold-tolerant pathogens in meat. Therefore a high incidence of *L. monocytogenes* could indicate a high incidence of other cold-tolerant micro-organisms, highlighting the danger of excessively high levels of *L. monocytogenes* on meat.

***Salmonella* spp.**

Sixty percent (n=30/50) of the samples analysed were found to be positive for presumptive *Salmonella* spp (Table 1). The National limit stipulated by the South African Department of Health (2000) is 0 (positive) $cfu.25g^{-1}$. However for Salmonellosis to develop levels must normally range between 10^7 and 10^9 $cfu.g^{-1}$ (Republic of South Africa, 2000). In this study the likely sources are probably incorrect slaughtering practices, which implies that bovine intestinal material known to contain *Salmonella* spp. contaminated the meat. Workers who are carriers of *Salmonella* spp. that practise poor personal hygiene may also contaminate the meat with *Salmonella* spp. According to Berends *et al.* (1997), levels of *Salmonella* spp. may be associated with the animals slaughtered during a particular day if the animals are thus highly contaminated, the same would be true for the meat derived from them. Berends *et al.* (1997) furthermore reported that once a production line is contaminated with *Salmonella* spp., the micro-organism will establish itself on the machinery, equipment and hands of workers and cause cross-contamination.

In a study done by Bacon *et al.* (2002) the prevalence of presumptive *Salmonella* spp. were reported to be 1.3% in 8 slaughtering plants. In a similar study by Madden *et al.* (2001) similar levels were found with 1.5% of the samples being positive for presumptive *Salmonella* spp. These results are much lower than the results obtained in this study.

Compliance of the various micro-organisms with proposed guidelines

Table 2 gives a summary of the averages of the micro-organisms over the sampling period compared with the proposed maximum limits and infectious doses. The South African Department of Health (2000) has proposed a maximum limit of 1000 $cfu.g^{-1}$ for *B. cereus* in raw meat. Therefore, when considering the averages of *B. cereus* obtained over the sampling period, 30% (n=15/50) of the samples did not comply with the guideline. An infective dose for *B. cereus* (10^5 $cfu.g^{-1}$) has also been proposed and may be defined as the dose where illness may result after consumption (Lattuada and McClain, 1998). Six percent (n=3/50) of the samples exceeded this dose and may thus result in illness if subjected to temperature and storage abuse. The average of *S. aureus* over the sampling period was 1.72×10^5 $cfu.g^{-1}$, thus 100% of the samples did not comply with the maximum limit of 100 $cfu.g^{-1}$ proposed by the South African Health Department. An infective dose of 10^5 cfu^{-1} has been proposed for *S. aureus*. Because 20% (n=10/50) of the samples exceeded this limit, illness may result if the meat is consumed after having been subjected to temperature and storage abuse.

The South African Department of Health (2000) stipulates a maximum limit of 100 $cfu.g^{-1}$ for *E. coli* on raw meat. In this study, the average *E. coli* over the sampling period was 3.4×10^5 $cfu.g^{-1}$ and therefore a total of 88% (n=44/50) of the samples did not comply with the guideline, whereas 4% (n=2/50) of the samples exceeded the infective dose of 10^6 $cfu.g^{-1}$. In the case of

Table 2. A summary of the level of compliance of the various micro-organisms to proposed guidelines.

Organism	Average cfu.g^{-1} (n=50)	Department of Health, National Guideline* cfu.g^{-1}	Percentage not complying	Infective guideline*	Percentage samples complying
B. cereus	8.32×10^3	1000	30	10^5	6
S. aureus	1.72×10^5	100	100	10^5	20
E. coli	3.4×10^5	10	88	10^6	4
L. monocytogenes	52% positive	100	-	unknown	-
Presumptive *Salmonella* spp.	60% positive	0 (positive) cfu.25g^{-1}	-	10^4	-

*Republic of South Africa (2000)

L. monocytogenes the samples were only analysed for presence or absence, and the results could not be expressed in terms of compliance and non-compliance. Forsythe (2000) reports that an infective dose for *L. monocytogenes* is unknown, but that it is believed to be linked to the different strains and the susceptibility of the consumer.

Correlation amongst the various bacterial groups

The correlation amongst the various micro-organisms are presented in Table 3. The aerobic plate counts correlated strongly (r = 0.960) with *Enterobacteriaceae*. The latter is an indicator organism of faecal contamination and unsanitary hygiene (Aberle *et al.*, 2001). Aerobic plate counts also correlated strongly (r = 0.970) with *Pseudomonas* spp. which is the largest genus present on fresh meat and thus one of the principal organisms present on meat. Finally the aerobic plate counts also correlated strongly (r = 0.703) with *S. aureus,* a principal inhabitant of the skin, glands and mucous membranes of animals and humans and therefore expected to occur in high numbers on meat. The low (negligible) correlation (r = -0.023) between *E. coli* and *Enterobacteriaceae* was surprising, as it had been expected that the former would constitute a considerable percentage of the *Enterobacteriaceae* family. A strong correlation (r = 0.892) was finally noted between *B. cereus* and *E. coli*. The correlation amongst the micro-organisms is important in casting light on possible associations between them during the processing stages. However, considering the relatively short period that the organisms inhabit the meat from slaughtering to deboning, as well as the low temperature maintained on the slaughtering line (0-10°C, deboning room), it is unlikely that any synergistic interactions took place. It is more likely that a correlation between specific microbial groups is a result of contamination during slaughtering and handling. For example, the correlation noted between *B. cereus* and *E. coli* may have originated from similar contamination sources such as the skin or faecal material (contamination during

Table 3. Summary of the correlation amongst the various bacterial groups.

	APC[1]	*Entero*[2]	*B. cereus*	*S. aureus*	*Pseudo*[3]	*E. coli*
APC[1]		0.960	-0.291	0.703	0.970	-0.104
***Entero*[2]**			-0.119	0.580	0.971	-0.023
B. cereus				0.012	-0.344	0.892
S. aureus					0.514	0.412
***Pseudo*[3]**						-0.248
E. coli						

[1] Aerobic plate count
[2] *Enterobacteriaceae*
[3] *Pseudomonas* spp.

evisceration) (Notermans *et al.*, 1997). Eisel *et al.* (1997) mentioned that high *E. coli* counts generally correlate with higher levels of foodborne pathogens originating from faecal origin, thus could be the reason why *E. coli* and *B. cereus* correlated with each other. It could therefore be deduced that the primary sources of contamination in this study could be of faecal, soil and hide origin, keeping in mind the high levels of the micro-organisms originating from these sources and the results from the questionnaire survey done by Nel *et al.* (2003) at the same deboning room, where it was found that the incoming carcasses were contaminated with faecal material, soil and hair. Success in showing the repetitive correlation amongst specific microbial groups contaminating fresh meat may lead to the identification of indicator organisms that may be indicative of the existence of others.

4. CONCLUSION

In conclusion the results indicate a definite risk of food poisoning in the event of the meat being exposed to a degree of temperature or storage abuse. Setting the possible risk of foodborne disease aside, the significant detrimental effect of elevated microbial counts on the shelf life, quality and sensorial properties of the product should not be overlooked. This holds obvious economic implications for the processing plant, particularly when keeping in mind the claim that food products from the deboning area are kept for up to 6 weeks before distribution to the retail market. In order to decrease these high incidences of micro-organisms it is recommended that significant improvements be implemented with regard to sanitation, slaughtering hygiene within the abattoir and especially in the deboning room, where the meat is exposed to considerable handling. Personnel should, for example, be educated and trained in limiting contamination of the carcasses whilst personal hygiene such as regular handwashing should be promoted, not only in the deboning room, but also upstream during the slaughtering process.

From the results it is evident that the existing food safety assurance system within the abattoir often fails to produce meat that complies with the National guidelines proposed for raw meat. Therefore, a need exists to re-evaluate the existing food safety assurance system (which include SOPs and GMPs) to ensure a microbiologically safe product to the consumer. Communication between the various role players including producers, retailers and consumers is also necessary, where each role player has his own responsibility in ensuring a product that is safe for consumption (Notermans *et al.*, 1998). The abattoir sampled in this study however, is one of only a select number of abattoirs with a quality assurance system (HACCP) in place and is considered a pioneer in the implementation of such a program within the South African abattoir industry. The data obtained during this study will furthermore be used to improve the existing quality assurance program at the specific abattoir and will thus ensure the delivery of a safe product to the consumer.

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CHAPTER 4

CONCLUSION

4. CONCLUSION

During the past decade numerous researchers have reported that the generally accepted traditional meat inspection procedures are no longer effective in producing microbiologically safe meat for the consumer and can not ensure that consumers will not be exposed to infectious doses of meat-borne pathogens. However, the matter of food safety has also grown in importance as a key issue for the general public. Around the world, therefore, meat inspection authorities are either encouraging or mandating the implementation of food safety measures for meat production and processing. These food safety measures should serve the purpose of health protection as well as safety and quality assurance in general for consumers.

Initial microbiological contamination of carcasses usually occurs during slaughtering where hygiene deficiencies can lead to considerable contamination. If the carcasses are exposed to high levels of contamination not even rigorous hygiene measures at a later stage of processing can compensate for this contamination. Therefore, verification of the hygienic processing and handling of meat is of the utmost importance. It thus became the purpose of this study to quantify the bacterial populations associated with meat from the deboning room of a red meat abattoir and to assess the personal and general hygiene practices of the workers employed inside the deboning room. Finally, conclusions were drawn on the identification of potentially hazardous micro-organisms associated with deboned meat.

4.1 THE PERSONAL AND GENERAL HYGIENE PRACTICES IN THE DEBONING ROOM OF A RED MEAT ABATTOIR.

In this study workers from the deboning room were interviewed by means of a questionnaire to ascertain their knowledge, beliefs and attitudes regarding personal and general hygiene. The results indicated that there are personal and general hygiene measures in place and that the workers adhere to most of them. However, the workers indicated that there is a need for more effective training in both personal and general hygiene practices. This also served to indicate that the workers have a positive attitude towards personal and general hygiene. It also emanated from the study that the workers know about practising personal hygiene such as handwashing, but do not know why they should do it. If the workers understood the purpose of practising optimal personal and general hygiene they would be more motivated to practise this. Apart from explaining to the workers the purpose of personal and general hygiene, training should be more structured: this implies that it should be done at regular intervals and more frequently for all the workers from one source, for example the supervisor or clinic sister, to ensure uniformity. This is also important in order for a HACCP or food safety program to be effective. Personal hygiene, general hygiene, standard operating procedures and good manufacturing practices are all prerequisites for the implementation and maintenance of any food safety program.

An important observation that was made during the interviews was the nature of the relationship between the workers and management. Before the commencement of the majority of interviews the workers enquired as to whether or not the supervisor would know who answered what. This indicated that a sound relationship between the workers and management was not eminent. The relationship between management and workers should be based upon mutual trust, respect, motivation and acknowledgement. This type of relationship would result in workers practicing optimal personal and general hygiene. It should always be borne in mind that hygiene does not only rely on one individual alone but on a team effort to be successful and effective.

4.2. BACTERIAL POPULATIONS ASSOCIATED WITH MEAT FROM THE DEBONING ROOM OF A GRADE A RED MEAT ABATTOIR

The incidence of micro-organisms associated with deboned meat were relatively high when compared to similar studies done. In some cases the results were compared with meat samples that were further processed such as in the case of ground beef. The counts obtained in this study were higher when compared to these processed samples, which indicated excessive contamination within the abattoir and deboning environment. Keeping these high levels in mind together with the fact that the results, almost without exception, exceeded the guidelines proposed by the South African Department of Health (2000), one is lead to the conclusion that the meat might pose a health risk when consumed, especially when the meat is subjected to temperature or storage abuse practices. In addition, if this meat is further processed the levels will be even higher, which might result in foodborne disease, cross-contamination between products and a reduced shelf life.

It emanated from the study that the existing food safety program within the abattoir often fails to produce meat that complies with national guidelines for raw meat. A further disconcerting finding of this study was that the slaughtering and deboning process at this abattoir is operated under a HACCP system implemented in accordance with regulatory recommendations and requirements. These recommendations and requirements are obviously not sufficient to ensure microbiologically safe meat. Not only does this hold implications regarding foodborne disease outbreaks and reduced shelf-life of products, but also obvious economic implications for the abattoir and deboning room. One foodborne disease outbreak could damage the abattoir financially to such an extent that it could result in the closing down of the abattoir and the workers losing their jobs. The most important recommendations include the identification of the major sources of contamination and micro-organisms frequently associated with red meat in order to be able to reduce or to prevent contamination and to re-evaluate the effectiveness of the existing HACCP system.

4.3 RECOMMENDATIONS AND PROPOSALS

4.3.1 Combining literature and empirical data to determine microbiological hazards in deboned red meat: a novel approach.

The question arises as to whether a hazard identification flow sheet together with literature and empirical data can be used to identify pathogens of concern on meat from the deboning room of a red meat abattoir and whether a revised hazard identification flow sheet, that could be used for the identification of relevant pathogens within the meat industry, could be compiled. Such a revised/simplified hazard identification flow sheet might be applied within the meat industry to identify relevant micro-organisms associated with a product such as deboned meat in order to ensure a microbiological safe product to the consumer.

Van Gerwen *et al.* (1997) developed a hazard identification flow sheet based on a previous approach by Notermans *et al.* (1994), for the identification of microbiological hazards in food products. Figure 1 represents the hazard identification flow sheet proposed by Van Gerwen *et al.* (1997). The starting point of the flow sheet is the listing of all the micro-organisms that are known to be pathogenic to man. Literature and expert knowledge can aid in selecting these pathogens (Notermans *et al.*, 1994). Thereafter, three options may be selected: rough hazard identification, detailed hazard identification and comprehensive hazard identification. Rough hazard identification entails selecting the most obvious pathogens that have been reported to have caused

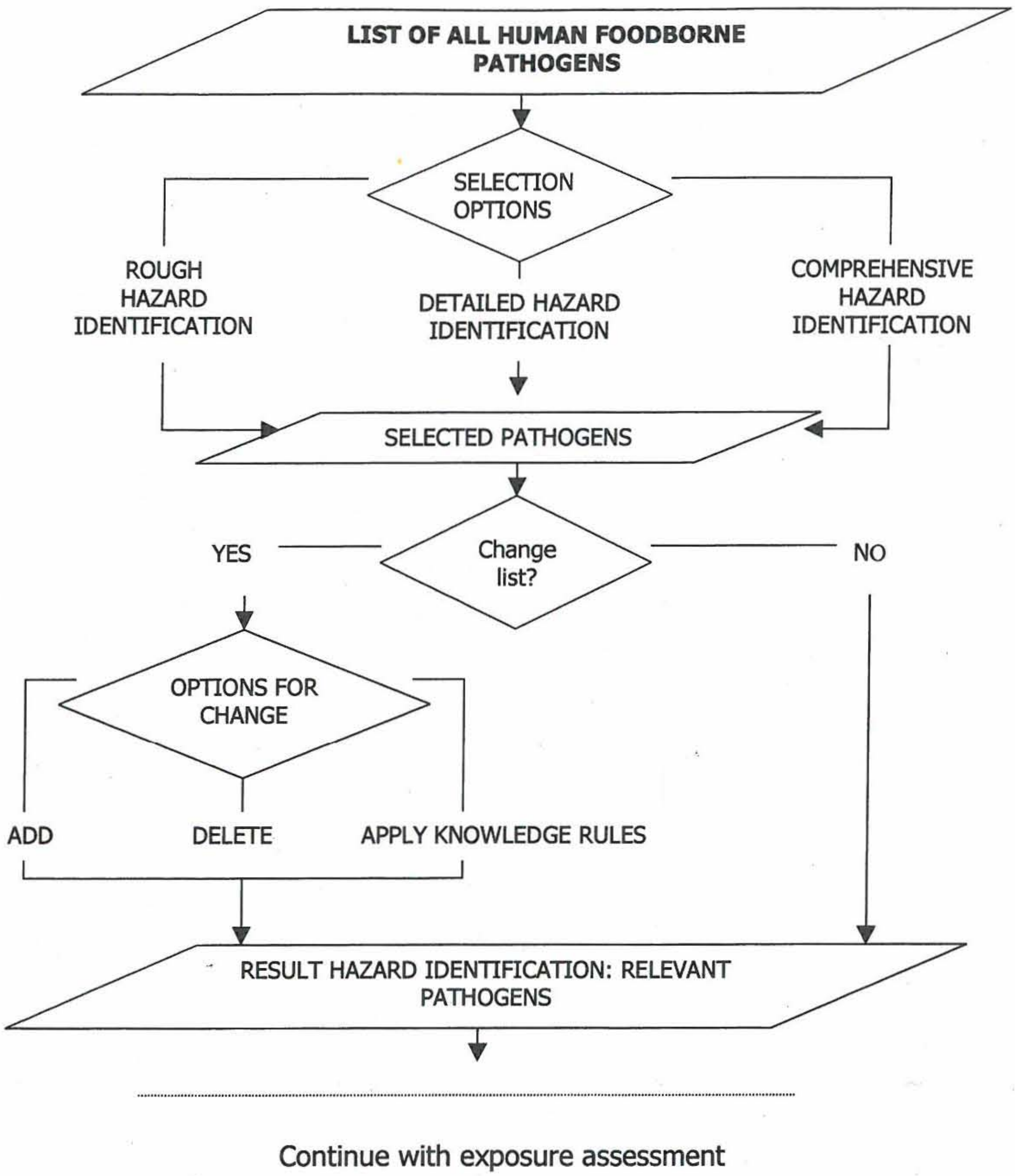

Figure 1: A schematic representation of the hazard identification procedure as proposed by Van Gerwen *et al.*, 1997.

foodborne outbreaks in the past. Detailed hazard identification includes the selection of pathogens which have been reported to be present in the ingredients of a product. Comprehensive hazard identification includes all identified human pathogens, which will also include unexpected recontamination of the product (Van Gerwen *et al.*, 1997). The next step includes the selection of knowledge rules in which relevant literature and expert advice is captured. The three types of knowledge rules include the presence or absence and survival or inactivation of pathogens, the general rules on pathogen characteristics and finally the rules concerning growth opportunities and toxin production. Van Gerwen *et al.* (1997) concludes the flow sheet with the final step, which results in a practical list of relevant pathogens from which the risks can be assessed (Figure 1).

4.3.1.1 Proposed adjustments to the hazard identification of Van Gerwen *et al.* (1997)

The following section is a proposed application of the hazard identification flow sheet of Van Gerwen *et al.* (1997) utilising the steps of rough hazard identification, detailed hazard identification and comprehensive hazard identification in order to identify the most relevant pathogens associated with deboned red meat and to suggest a revised and unique hazard identification flow sheet for the deboning area of a red meat abattoir.

Rough hazard identification

During this step pathogens associated with deboned meat were identified. The results obtained from chapter 3 were used as a source of empirical data. In chapter 3 the following pathogens were found to be present: *B. cereus, S. aureus, L. monocytogenes, E. coli,* presumptive *Salmonella* spp. and largest group of spoilage micro-organisms, *Pseudomonas* spp. A further consideration during this step was the implication of these pathogens in foodborne disease outbreaks (Notermans and Borgdorff, 1997; Nortjè *et al.*, 1999; Borch and Arinder, 2002). The rough hazard identification step resulted in the following pathogens being listed in Table 1; *B. cereus, S. aureus, L. monocytogenes, E. coli* and presumptive *Salmonella* spp.

Detailed hazard identification

According to the NACMCF (1999) and Borch and Arinder (2002) the following micro-organisms may contaminate the meat during slaughtering and deboning: *Campylobacter, C. botulinum, C. perfringens and Pseudomonas* spp. Therefore these micro-organisms were included in Table 1. Because this resulted in a long list of micro-organisms it was necessary to select those most likely to cause foodborne disease. Knowledge rules were applied in the compilation of this selection (Van Gerwen, *et al.*, 1997).

Knowledge rules:

Type 1

This step included the selection of pathogens that were able to survive in the end product. In this study the retail cuts were vacuum-packed and then distributed to the retail markets maintaining the cold chain between 0 and 5°C. It was necessary to evaluate each micro-organism (listed in Table 1) in relation to its oxygen requirements and also to consider the formation of spores, in order to assess whether the micro-organism could survive the vacuum-packaging process.

Because *B. cereus* is a facultative anaerobe as well as a sporeformer (Notermans *et al.*, 1997; Mosupye and Von Holy, 2000), it is able to survive vacuum-packaging. *S. aureus, E. coli, Salmonella* spp. and *L. monocytogenes* are all

Table 1: Results of the identification procedure applied to deboned vacuum-packed meat after application of empirical data, literature and knowledge rules

Rough hazard identification	Detailed hazard identification	Knowledge rules			Comprehensive hazard identification
		1[a]	3[b]	1 and 3	
B. cereus	*B. cereus*	X	X	X	X
S. aureus	*S. aureus*	X	X	X	X
E. coli	*E. coli*	X	X	X	X
Salmonella spp.	*Salmonella* spp.	X	X	X	X
L. monocytogenes	*L. monocytogenes*	X	X	X	X
	Campylobacter spp.		X		X
	C. botulinum	X	X	X	X
	C. perfringens	X	X	X	X
	Pseudomonas spp.	X			X

[a] Ability of micro-organism to survive in product
[b] Ability to produce a toxin

facultative anaerobes and may thus also survive the vacuum-packaging process (Vorster *et al.*, 1994). These pathogens have therefore not been removed from the pathogen list (Table 1). *Campylobacter* spp., on the other hand, is a microaerophile, growing optimally in atmospheres containing 5 – 10% oxygen and 3 – 5% carbon dioxide and thus very sensitive to oxygen (Forsythe, 2000). There is therefore a small possibility that *Campylobacter* spp. may survive vacuum-packaging. Both *C. botulinum* and *C. perfringens* are anaerobes, with *C. perfringens* being a sporeformer that might survive the vacuum-packaging process (Johns, 1991). Neither *C. botulinum* nor *C. perfringens* was therefore removed from the pathogen list presented in Table 1. Although *Pseudomonas* spp. are spoilage organisms and aerobic, research has shown that although the numbers of *Pseudomonas* spp. decrease during vacuum-packaging, it may survive the process and is therefore not removed from Table 1 (Lee and Yoon, 2001). The application of knowledge rule 1 thus resulted in a list of six pathogens and one spoilage micro-organism.

Type 2

For the purpose of this study, knowledge rule 2 has been omitted because it has already been dealt with during the rough hazard identification step through using the results from chapter 3 as empirical source.

Type 3

Pathogens were selected that were able to grow or produce toxins in the product. Both *B. cereus* and *S. aureus* are toxin producers and are also capable, owing to their nutritional requirements, of growing in the meat (Portocarrero *et al.*, 2002; Thunberg *et al.*, 2002). Some *E. coli* groups produce toxins while others do not. The groups that produce toxins include Enterohaemorrhagic and Enteroaggregative *E. coli* (Forsythe, 2000). Van Gerwen *et al.* (1997) indicate that both *Salmonella* spp. and *L. monocytogenes* should remain on the pathogen list, which implies that, in spite of the fact that the application of a knowledge rule omits *Salmonella* spp. and *L. monocytogenes*, these pathogens should not be removed from the pathogen list. *Campylobacter, C. botulinum* and *C. perfringens* are toxin producers and are therefore not removed from Table 1. *Pseudomonas* spp. on the other hand does not produce toxins when growing or multiplying in or on the meat (Lee and Yoon, 2001). The remaining pathogens, after the application of all the knowledge rules (Table 1) were *B. cereus, S. aureus, Salmonella* spp., *L. monocytogenes, C. botulinum* and *C. perfringens*.

Comprehensive hazard identification

Pathogens that may recontaminate the product were be included in the pathogen list represented in Table 1. According to Mosupye and Von Holy (2000) and Forsythe (2002) the above-mentioned pathogens may recontaminate the meat via sources such as equipment and food handlers preparing or processing the food. Therefore both *Campylobacter* and *Pseudomonas* spp., which were excluded from the pathogen list during the initial step of the rough hazard identification step had to be replaced.

The proposed application study of the three levels of detail and the knowledge rules resulted in a pathogen list which includes: *B. cereus, S. aureus, L. monocytogenes, E. coli,* presumptive *Salmonella* spp., *Pseudomonas* spp. *Campylobacter* spp., *C. botulinum* and *C. perfringens*. According to Basaillon *et al.* (2001) further characterisation (which includes exposure assessment, dose-response assessment and risk characterisation) is necessary for the micro-organisms which remain after the application of a hazard identification procedure.

Applicability

The application of literature and empirical data in this study has resulted in the proposal of a revised hazard identification flow sheet (Figure 2). The initial step was to list all the micro-organisms associated with a specific foodstuff (not all human foodborne pathogens) through the consultation of empirical data, epidemiological and expert knowledge. This will result in rough hazard identification. During the second step (detailed hazard identification) relevant micro-organisms were selected through the application of knowledge rules. Finally comprehensive hazard identification entailed the exclusion and inclusion of certain micro-organisms because of their ability to recontaminate the product during handling or processing. This resulted in the final list of micro-organisms for which further characterisation is necessary.

The majority of micro-organisms identified during the hazard identification process were enumerated in Chapter 3 except for *C. botulinum, C. perfringens* and *Camphylobacter*. This indicated that the results of Chapter 3 gave a relatively comprehensive overview of the majority of pathogens associated with deboned meat. This hazard identification procedure should be effective in identifying micro-organisms, especially if applied by the meat industry within the HACCP system. If the relevant micro-organisms of a specific foodstuff are known, specific control measures can be implemented to reduce the levels or to prevent the occurrence of specific micro-organisms in the meat.

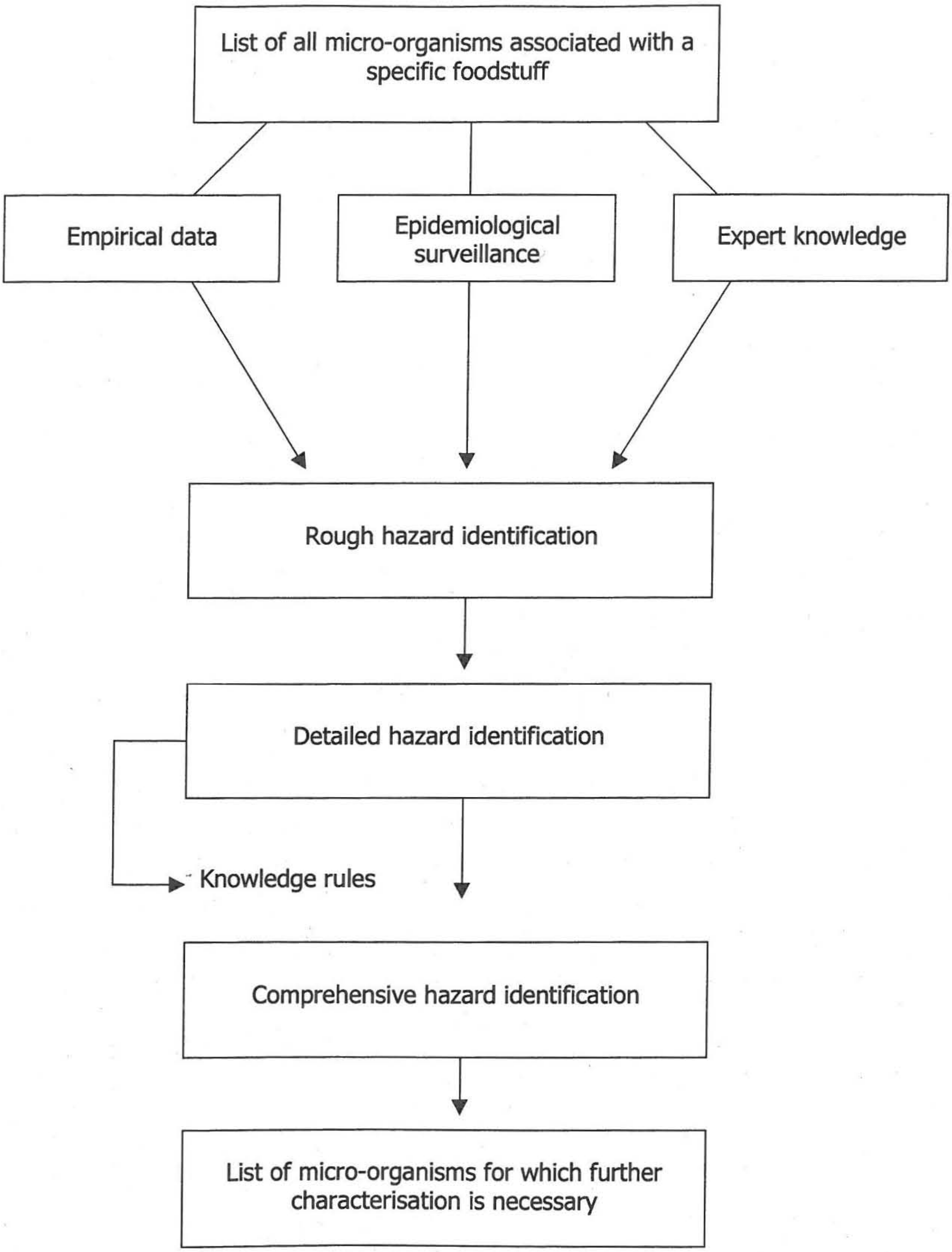

Figure 2: Schematic representation of the proposed, simplified hazard identification flow sheet for red meat.

4.3.2 Recommendations to industry

From the results generated in the study it can be concluded that the abattoir are experiencing difficulties in producing meat that complies with the national guidelines. The abattoir is also failing to produce meat that is uniform in microbiological levels on a day to day basis. From the results outlined in chapter 2 it can be deduced that some personal and general hygiene practices are in place and that the personnel conform to the majority of them. However, when considering the results generated from chapter 3 one is led to ask the question: if the deboning room and associated hygiene practices is a less significant contributor of contamination, what source is then predominant ?. In chapter 2 the respondents that were employed at the carcass receiving point in the production line were questioned on the "cleanliness" of the incoming carcasses, these respondents indicated that they encounter hair and skin (source of *S. aureus*), faecal material (source of *E. coli*, *Salmonella* spp.) and soil (source of *B. cereus*) on a daily, weekly and monthly basis. This agrees with the high levels of the pathogenic micro-organisms analysed in chapter 3. Therefore, a possible origin of contamination might be the slaughtering floor during improper slaughtering techniques such as hide removal and evisceration. The slaughtering floor is thus failing to live up to the prerequisite programs of food safety systems such as SOPs and GMPs that can be controlled in order to ensure meat with a reduced microbiological load. It is of the utmost importance to pin-point the cause and origin of the contamination in order to concentrate on developing and implementing intervention programs. Intervention programs for improper slaughtering techniques includes, amongst others, pre-evisceration treatment, sanitary hide removal or even chemical hide removal.

The hazard identification process that was discussed under 4.3.1 this chapter is a practical tool that can be used by management in identifying the micro-organisms associated with red meat. This will also guide management in not only identifying the micro-organisms of concern but also identifying the sources of the identified micro-organisms. This again highlights the necessity and importance of the indispensable interaction amongst scientists, veterinarians, meat inspectors and abattoir managers (the industry) in delivering a microbiologically safe product.

The information obtained in this study could aid policymakers in better-informed decision making. The complexity, size and cost of our food production systems and the potentially large adverse effects that could result from poorly informed, *ad hoc* policy decisions, have consequently, rendered the traditional approaches in producing safe meat untenable. To adopt quantitative approaches to manage foodborne risks could improve the effectiveness and efficiency of food safety regulations, making regulatory decisions more transparent. Finally, the complexity of our food safety problems mandates multidisciplinary approaches, a process that requires cooperation and collaboration between a wide range of disciplines, bringing the best approaches from various sciences to bear in the task of finding effective and efficient solutions to safe food production.

The following specific recommendations are made to industry:

- regular sampling of the meat and surfaces should be performed to determine the microbiological levels on the meat products and surfaces;
- management should strive to establish employee commitment regarding personal and general hygiene;
- continuous and effective supervision over workers should be practised
- training should be done on a structured basis;
- a cleaning schedule should be implemented within the deboning room;
- the workers should be trained to conform to and effectively maintain the cleaning schedule; and

- a system should be implemented where workers are acknowledged for practising optimal personal and general hygiene;
- a daily surveillance and documentation of cleaning procedures by visual evaluation in the morning before slaughtering and deboning, as well as upon monthly bacteriological sampling to prove the effectiveness of cleaning and disinfection should be maintained;
- process-orientated hygiene standards and especially "critical check" points have to be surveyed daily with special attention to the behaviour of the staff. It is advisable to use check lists for documentation;
- Not only must the SOPs and GMPs be implemented, verified and maintained correctly and effectively within the deboning room but also on the slaughtering floor. This is a pre-requisite for a HACCP program.

4.4 FUTURE RESEARCH

With reference to this study, further research opportunities might include the following:

- further studies on the occurrence of other micro-organisms (including fungi and parasites) associated with deboned meat;
- conducting similar studies in other divisions of the abattoir such as the slaughtering floor;
- further studies into the remaining three steps of risk assessment: exposure assessment, dose response assessment and risk characterisation;
- the launching of an educational and awareness projects regarding personal and general hygiene practices to the workers inside the deboning room as well as on the slaughtering floor;
- the implementation of a pathogen reduction project on a National level (Department of Agriculture) that may include an investigation into the microbiological status of South African meat that will aid decision makers in implementing intervention programs;
- the implementation of intervention programs such as pre-evisceration treatments or chemical removal of hair on the cattle, in order to assess whether it contributes to a significant reduction in the microbiological levels on the meat.

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APPENDIX A

**QUESTIONNAIRE:
THE PERSONAL AND GENERAL HYGIENE PRACTICES IN THE DEBONING ROOM OF A RED MEAT ABATTOIR**

The personal and general hygiene practices in the deboning room a red meat abattoir

For official use.

Questionnaire

This is an anonymous survey

Mark answer/s with "x".

Questionnaire number: 1

Are you a member of the permanent or temporary staff? P ☐ 2 T ☐ 3

Section A: Personal hygiene

1. How often do you wash your hands before entering the deboning room?

   a) Never ☐ 4
   b) Always ☐ 5
   c) Only after visiting the toilet ☐ 6
   d) Sometimes (specify)... 7
   8
   9

1.1 Referring to question 1, with what do you wash your hands?

   a) Hot water and soap ☐ 10
   b) Cold water and soap ☐ 11
   c) Only hot water ☐ 12
   d) Only cold water ☐ 13
   e) Other (specify)... 14
   15

1.2 Referring to questions 1.2 (a) and (b), how often is soap available?

   a) Never ☐ 16
   b) Always ☐ 17
   c) Most of the time ☐ 18
   d) Sometimes ☐ 19
   e) Other (specify)... 20
   21
   22

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2 With what do you dry your hands?

a) Nothing 23
b) Disposable paper towel 24
c) Towel/cloth 25
d) Against clothes 26
e) Other (specify).. 27
.... 28

3 Which of the following protective clothing do you wear?

a) Overall 29
b) Apron 30
c) Hairnet 31
d) Beardnet 32
e) Hardhat 33
f) Gumboots 34
g) Latex gloves 35
h) Stainless steel gloves 36
i) Other (specify).. 37
.... 38

3.1 How often do you wear washed protective clothing?

a) Daily 39
b) Once a week 40
c) Twice a week 41
d) When excessively soiled 42
e) Other (specify).. 43
.... 44

3.2 How often do you wash your gumboots before entering the deboning room?

a) Never 45
b) Always 46
c) Other (specify).. 47
.... 48

4 If you wear stainless steel gloves how often do you sterilise them?

a) Never 49
b) After breaks 50
c) Daily 51
d) Once a week 52
e) Other (specify).. 53

54

55

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5 Do you report disease/illness to management?

a) Yes 56
b) No 57
c) Other (specify).. 58
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5.1 If yes at question 5, what action is taken from management?

a) No action 60
b) Medical examination 61
c) Get sickleave 62
d) Other (specify).. 63
.... 64

6 What action do you take when you cut yourself?

a) Nothing, commence with open wound 65
b) Report to management and cover with waterproof plaster and disposable glove 66
c) Other (specify).. 67
.... 68

7 Do you do the following in the deboning room?

Y N

a) Smoke 69
b) Eat 71

8 Do you work with the following jewellery inside the deboning room?

Y N

a) Rings 73
b) Earrings 75
c) Necklaces 77
d) Watch 79
e) Other (specify).. 81
.... 83
85
87

9 Is there supervision to ensure that you (the worker) practice a high level of personal hygiene?

a) Yes 89
b) No 90

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9.1 If yes at question 9, how often?

a) Once a day
b) Twice a day
c) Throughout the process
d) Other (specify)..
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92
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96

10 Do you (the worker) receive training in personal hygiene?

a) Yes
b) No

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98

10.1 If yes at question 10, specify:..
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100
101

10.2 Do you feel that the training is effective and improve knowledge?

a) Yes
b) No
c) Give reasons for "no"..
....

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103
104
105
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11 Are there disciplinary actions taken if you don't adhere or comply to the personal hygiene requirements and rules?

a) Yes
b) No

107
108

11.1 If yes at question 11, specify the actions...................................
....

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110

12 Do you undergo medical examinations?

a) Yes
b) No
c) Give reasons for "no"..
....

111
112
113
114

12.1 If yes at question 12, how often?

a) Once a month
b) Once every 3 months
c) Once every 6 months
d) Annually
e) Other (specify)..

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116
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120

Section B: General hygiene

1. How often do you sterilise your knives and hooks?

a) Never 121
b) Daily 122
c) After breaks 123
d) During shifts 124
e) When excessively soiled 125
f) Other (specify).. 126
.... 127

2. How often are working surfaces cleaned and disinfected?

a) Never 128
b) Daily, before commencing with work 129
c) Between shifts 130
d) During shifts 131
e) Other (specify).. 132
.... 133

2.1 With what are surfaces cleaned/disinfected?

a) Hot running water 134
b) Cold running water 135
c) Hot running water and detergent 136
d) Cold running water and detergent 137
e) Other (specify).. 138

2.2 Elaborate on how the conveyor belt are cleaned/disinfected. 139
.... 140
.... 141
.... 142

3. What action do you take if meat falls on the floor?

a) Notify management 143
b) Pick up and back on line (conveyor belt) 144
d) Pick up and wash off with clean water 145
d) Pick up and condemn 156
e) Leave on floor (no action) 157
f) Contaminated area trimmed off 158
g) Other (specify).. 159
.... 160
161
162

4. Are carcasses visibly clean (free of hair,grass etc.) when entering the deboning room, from the slaughter room?

a) Yes ☐ 163
b) No (specify).. 164
.... 165
166

5. How often do you encounter the following in/on the meat?

	Daily	Weekly	Mon	Annu
a) Abscesses	167	168	169	170
a) Measles	171	172	173	174
b) Parasites	175	176	177	178
c) Feacal/bile contamination	179	180	181	182
d) Hair and/or skin	183	184	185	186
e) Soil and/or grease	187	188	189	190
f) Other (specify).................................	191	192	193	194

.... 195
.... 196

5.1 When encountered the above, what action do you take?

a) Notify management ☐ 197
b) Remove/trimming of contaminated area ☐ 198
c) Nothing ☐ 199
d) Other (specify).. 200
.... 201

6. How often do you encounter the following

	D	W	M	A
a) Rats and mice				
b) Flies				
c) Cockroaches				
d) Other (specify)..				

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206
210
214
218
219

7. Do you (the worker) receive training in general hygiene?

c) Yes ☐ 220
d) No ☐ 221

7.1 If yes at question 7, specify:... 222
.... 223
224

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7.2 Do you feel that the training is effective and improve knowledge?

d) Yes 225

e) No 226

f) Give reasons for "no"... 227

.... 228

229

7.3 Are there disciplinary actions taken if you don't adhere or comply to the general hygiene requirements and rules?

c) Yes 230

d) No 231

7.4 If yes at question 7.3, specify the actions... 232

.... 233

234

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