CHAPTER 2

LITERATURE REVIEW

2.1.1 EPIDEMIOLOGY OF FOODBORNE ILLNESSES ASSOCIATED WITH RAW BEEF

Food-borne diseases are increasingly being recognized as a major cause of morbidity in both industrialized and developing countries, and also of mortality in the latter. However, the full extent of the social and economic impacts is hard to measure due to underreporting of cases (Sofos, Belk & Smith, 1999b; Todd, 1989). Analogously, South Africa is also caught in the same web but the underreporting in this case can be attributed to the current health regulation. The regulation states that notification is required only when five or more cases are reported by one physician or at one medical institution (Department of National Health and Population Development, South Africa, 1989).

Studies done by various authors indicate that the foods of animal origin are the main vehicles of pathogens in human foods. These animal products mainly meat, fish, poultry, have been implicated in food-borne diseases as the live animals are exposed to a variety of potential sources of microorganisms at the various rearing points (Bean & Griffin, 1990; Sofos *et al.*, 1999b). The microorganism sources are diverse and include soil, water, feed, air and other animals (Ayres, 1955). In healthy animals the microorganisms are confined primarily to the gastrointestinal tract and exterior surfaces such as hide, hooves and hair. But during slaughtering and dressing the meat usually becomes contaminated with these microorganisms and the extent of contamination depends to a large degree on the basic good manufacturing practices of the abattoir (Ayres, 1955; Mackay & Derrick, 1979). However, there has been an increased safety concern with meat and meat products as there seem to be an increased occurrence of food-borne diseases with the consumption of these products (Bean & Griffin, 1990; Cross, 1996; Dean, 1991; Roberts *et al.*, 1984; Tompkin, 1990; Wood *et al.*, 1998).

In South Africa despite lack of pathological reports, work done by various researchers has shown the possibility of contamination of meat products by various pathogens. For instance, Vorster (1994) reported that South African meat and meat products are contaminated with bacterial pathogens though not at high levels, but could easily pose a health risk to immuno-compromised individuals. Prior to the study carried out by Vorster (1994), Nortjé (1987) in his study on the meat chain had made various recommendations, which could assist in lowering microbial loads in the meat products. These included a strict adherence to the maintenance of the cold chain throughout the meat production chain and an effective management of sanitation programmes from the abattoir to the markets, failure of which there would still be high levels of contamination on the South African meat products. Unfortunately this recommendations seems not to have been implemented as Vorster, Greebe & Nortjé (1994) showed the presence of pathogens such as *Escherichia coli* and *Staphylococcus aureus* in the retail meats of South Africa. A recent study done by Nortjé, Vorster, Greebe & Steyn (1999), have also shown the occurrence of *Bacillus cereus* and *Yersinia enterocolitica* in retail meats and further reiterated the need to implement methods to prevent the entry or proliferation of these pathogens in meat products.

The urgency to effect control of these microorganisms is to avoid outbreaks of food-borne disease associated with similar organisms, which have occurred in other countries. Reported food-borne outbreaks from other countries notably the United States have shown that if human illnesses are ranked by organ system gastrointestinal infections rank second in incidence. For instance in 1990 an average of 35,000 to 40,000 deaths were attributed to gastrointestinal infections with food being the vehicle in one-third of the total number of incidences (Jackson, 1990). A survey done by Todd (1992) in Canada indicated that microorganisms particularly *Salmonella, Staphylococcus aureus, Clostridium perfringens,* and *Bacillus cereus* were the main etiologic agents and the foods involved were mainly meats and poultry has which has a higher number (No) of cases (Table 2.1.).

Table 2.1: Foods associated with food-borne incidents in Canada 1975-1984 (Todd, 1992).

Food type	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Mean	
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	%
Meat	276	219	192	185	191	165	128	209	195	228	199	23
Seafood	50	54	52	65	50	54	45	78	70	68	59	7
Poultry	74	74	63	79	81	96	82	94	100	146	89	10
Eggs	1	-	3	6	4	6	4	1	3	4	3	<1
Dairy foods	21	32	42	33	43	29	33	71	86	104	49	6
Bakery foods	67	74	67	65	69	53	47	81	70	81	67	8
Infant foods	5	11	11	12	15	12	10	22	13	16	13	2
Confectionery	12	14	12	15	11	9	10	12	8	22	13	1
Vegetable	34	43	29	53	35	31	42	32	31	48	38	4
Fruit	15	21	29	42	34	34	42	37	38	35	33	4
Chinese foods	39	52	58	49	54	61	37	50	62	67	53	6
Salads	22	24	28	32	24	17	19	29	21	42	26	3
Sandwiches	33	23	26	28	26	20	17	42	35	41	29	3
Beverages	28	16	24	28	19	32	35	53	37	55	33	4
Others or unknown foods	160	203	141	144	169	140	96	177	194	223	165	19
TOTAL	837	860	777	836	825	759	647	988	963	1180	868	100

Between 1968 and 1977, prior to the study carried out by Todd (1992), 58% of all reported outbreaks of food-borne illnesses were also associated with meat and poultry. This figure subsequently, dropped to 33% in 1977 to 1984 (Bryan, 1980).

The impact of the food-borne diseases on the meat industry worldwide has been multifold and is felt amongst all the stakeholders from the producer to the consumer (Food and Drug Administration (FDA), 1999). The South African meat industry being part of the global world market has not remained neutral. Drawbacks due to not only the incidences of food-borne diseases but other factors such as changes in eating habits have come into play affecting demand (Grijspaardt-Vink, 1996). For instance per capita meat production in South Africa dropped by about 25% between 1989 and 1997 (Food and Agricultural Organization (FAO), 1997).

In addition, to the microbial related food-borne diseases various other scandals have also rocked the meat market. These include the recent cases in Britain in which cows were found with bovine spongiform encephalopathy (mad cow disease) which is potentially lethal to man (Alisa, 1996; Bryan, Guzewich & Todd, 1997). More recently, dioxin contamination of animal feed in Belgium was reported (World Health Organization, 1999). Emergence of 'new' pathogens has also caused a threat to food safety (Cox, 1989; Farber, 1991; Palumbo, 1986). Hazard management is currently the best approach to the control of these emerging pathogens especially when they display similar ecological and physiological characteristics as the existing known pathogens (Harrigan, 1998; Tarrant, 1998). Hazard management more so is necessary for meat slaughterhouses as the operations lack a definitive step that can be relied upon to eliminate microbiological risks (Buchanan & Whiting, 1998).

2.2 MEAT BACTERIA OF HEALTH CONCERN

Meat is a nutrient rich substrate that can support growth of a wide range of microorganisms if not properly handled, processed and preserved. The microorganisms are introduced into the otherwise sterile interior of the meat surface by translocation of bacteria from the surface of the carcass. The ease of translocation depends on the degree of contamination and/or abusive conditions of handling and storage. These factors allow microbial proliferation, increase the potential for the presence of pathogenic bacteria and formation of toxins (Ayres, 1955; NACMCF, 1993; Nottingham, 1982; Sprenger, 1995; Sofos *et al.,* 1999a; Sofos *et al.*, 1999b).

In general, the presence of all these specific bacteria on the meat is dependent on the storage temperature, pH, moisture content, oxygen availability and the general handling of the carcass. It should be noted that as storage temperatures are lowered there is a significant decrease in the rate of microbial growth as well as a reduction in the diversity of the microbial flora. The moisture content of meat is also fairly high. With a water activity (a_w) of 0.99 this supports the growth of a wide variety of bacteria. Growth of bacteria is also dependent on the pH of the substrate but growth is restricted at the lower end of the pH range. Therefore meat whose pH range is usually 5.3-6.5 would support the growth of a wide variety of bacteria. The pH of meat is influenced by various factors such as feeding and handling practices at the time of slaughter (NACMCF, 1993).

The nature and level of microbial contamination has important consequences in relation to public health, storage life and the type of spoilage likely to arise. Contamination with spoilage microorganisms may lead to product losses and therefore economic losses, whereas presence of pathogens or their toxins may be the cause of food-borne diseases (NACMCF, 1993; Nottingham, 1982; Sofos *et al.*, 1999a; Sofos *et al.*, 1999b). Raw meats are especially important sources of pathogens like *Salmonella* and *Clostridium perfringens,* that are often incriminated in outbreaks of food-borne diseases (refer section 2.2.1.2 and 2.2.2). Raw meat are also sources of *Staphylococcus aureus, Yersinia enterocolitica, Listeria monocytogenes, Campylobacter jejuni* and *Escherichia coli* (Bean, Griffin, Goulding & Ivey, 1990; Nottingham, 1982; Nortjé *et al.*, 1999; Vorster *et al.*, 1994).

The primary source of these carcass microbes starts from the animals' pre-slaughter environment as illustrated in Table 2.2.

Table 2.2: Sources of some bacteria of health concern in meat (Church & Wood, 1992).

Organism	Principle source
Staphylococcus aureus	Skin, mucous membranes of handlers
Clostridium perfringens,	Soil, intestinal tract
Listeria monocytogenes	soil, water, air or intestinal tract
Enteropathogenic *Escherichia coli*	Intestinal tract
Yersinia enterocolitica	Intestinal tract
Salmonella spp.	Intestinal tract

All these bacteria are of importance as they are usually associated with food poisoning of sorts (Figure 2.1). Food poisoning bacteria are ubiquitous and will be found in any food processing plant, which makes it imperative for all food processors to adopt a system of hygiene management to minimize or prevent the risk of illness from consuming contaminated food. The type of pathogens in a food is subject to the conditions to which the food is exposed to before and after processing. This can be emphasized by the study carried out by Nortjé, Nel, Jordaan, Naude, Holzapfel & Grimbeek (1989) on the retail markets of South Africa indicating that temperature abuse is usually prevalent in the supermarkets. Such abuse of storage conditions can allow growth of various pathogens such as *Clostridium perfringens.* The chance that the product might be inadequately cooked may lead to increased risks with consumption. The continuity of temperature maintenance of the cold chain is very important to reduce or stop the growth.

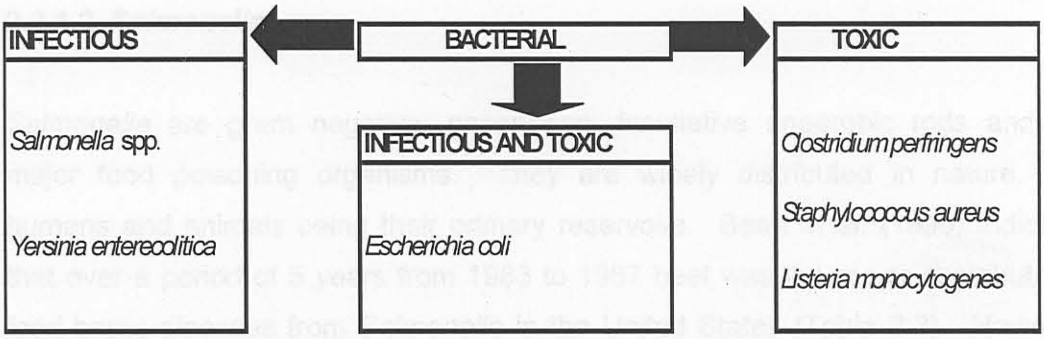


Figure 2.1: Types of food poisoning associated with meat pathogens (adapted from: Sprenger, 1995).

2.2.1 Enterobacteriaceae

The main Enterobacteriaceae species of interest in the meat industry are *Salmonella, Yersinia* and *Escherichia coli.* These are gram negative rods that cause food-borne gastroenteritis. They are mainly found in the animal intestine, soil and plants from where they can contaminate the food chain. They are regarded as indicators of faecal contamination when present in foods and are commonly isolated from hooves and hides of cattle (Stolle, 1981).

2.2.1.1 *Escherichia coli*

Escherichia coli is a gram negative, aerobic rod with certain strains that are pathogenic and produce an enterotoxin. Raw beef can be an important vehicle in the transmission of *E. coli* 0157:H7 (Doyle & Shoeni, 1987). The symptoms in man are usually a watery diarrhea and the disease is most commonly associated with travelers.

Escherichia coli generally, comprises a greater proportion of the total aerobic flora of the intestine than of the hide and its presence in meat is usually a result of faecal contamination or when the intestinal tract is punctured. Control of this pathogen is mainly assured by proper slaughtering techniques, hygiene during slaughtering and dressing together with prompt adequate cooling (Church & Wood, 1992; Nottingham, 1982).

2.2.1.2 *Salmonella*

Salmonella are gram negative, nonsporing, facultative anaerobic rods and are major food poisoning organisms. They are widely distributed in nature, with humans and animals being their primary reservoirs. Bean *et al.* (1990) indicated that over a period of 5 years from 1983 to 1987 beef was the major contributor to food-borne diseases from *Salmonella* in the United States (Table 2.3). However, NACMCF (1993) reported that currently the incidence rates of *Salmonella* on raw beef are generally, low (<5%). However, Hogue *et al.* (1993) and Stolle (1981) indicated that the levels are relative and can be fairly high depending on the health or handling of the animals during slaughter.

Salmonella species are maintained within the animal population by means of nonsymptomatic animal infections and in animal feeds. This leads to both sources serving to keep slaughter animals reinfected in a cyclical manner (Brown, 1982). The increased incidence of *Salmonella* in slaughter animals is also usually associated with transport of animals in overcrowded, dirty vehicles and poor hygiene in the abattoirs, resulting in spread of infection and an increase in contamination of carcasses by faecal material and intestinal matter. In slaughter animals faecal matter is of great importance as it is usually the source of animal hide contamination. (Nottingham, 1982).

Table 2.3: Leading vehicle foods known for salmonellosis outbreaks in the United States, 1973-1987 (Bean & Griffin, 1990).

Rank	Vehicle foods	Outbreaks	Percentage
1	Beef	77	9.7
2	Turkey	36	4.5
3	Chicken	30	3.8
4	Ice cream	28	3.5
5	Pork	25	3.2
6	Dairy products	22	2.8
7	Eggs	16	2.0
8	Bakery products	12	1.5
9	Mexican foods	10	1.3
10	Fruits and vegetables	9	1.1

Salmonella species are of importance as they cause diarrhea and systemic infections, which can be fatal in particularly susceptible persons, such as the immunocompromised, the very young, and the elderly. Due to these serious side effects of *Salmonella* poisoning and potential fatalities (Table 2.4), its presence in food is usually expected to be negative. The *Salmonella* outbreaks, cases and deaths associated with foods in the United States over a period of 5 years are as shown in Table 2.4. Various factors, like increased mass food preparation, mass storing of food, international trade and decreased resistance to infection, have contributed to increased incidence of food-borne salmonellosis (FDA/ CFSAN, 1999; Nottingham, 1982).

The habit of eating raw or insufficiently heated foods, is the main cause of salmonellosis. This is because the food inspection methods in use in the meat industry do not indicate S*almonella* presence or absence as they are not visual (Brown, 1982). Therefore, control of this pathogen can only be assured by hygiene during slaughtering and dressing in addition, to prompt adequate cooling (Church & Wood, 1992; Nottingham, 1982).

Table 2.4: Salmonella outbreaks, cases and deaths traced to foods in the United States, 1983-1987 (Bean et al., 1990).

Years	Outbreaks/Cases/Deaths
1983	72/2427/7
1984	78/4479/3
1985	79/19660/20
1986	61/2833/7
1987	52/1846/2

2.2.1.3 *Yersinia*

Yersinia is a psychrotrophic, gram negative, facultative anaerobic rod. Interest in this specific pathogen has increased over the years due to the fact that unlike most pathogens, it is capable of growth at 5°C competitively with normal microflora. It can grow readily in beef held at 1-7 °C (Palumbo, 1986).

2.2.2 *Clostridium perfringens*

Clostridium perfringens is a gram-positive, spore forming anaerobe. The food poisoning strains of interest is mainly type A. It is widely distributed in nature and is found in soils water, foods, dust and in the intestinal contents of virtually every animal including man (Church & Wood, 1992; Nottingham, 1982; Sprenger, 1995). Meat and poultry animals are the most common vehicles of transmission (Smart, Robert, Stringer & Shah, 1979). This is because *Clostridium perfringens,* requires many amino acids or simple peptides and several vitamins which are provided easily by red meat and poultry (Craven, 1980). However, the foods mainly involved in *Clostridium perfringens,* outbreaks are often meat dishes (Smart *et al.,* 1979). *Clostridium perfringens* gets into meats directly from slaughter animals or by subsequent contamination of slaughtered meat from containers, handlers or dust. Since it is a spore former it can withstand the adverse environmental conditions of drying, heating and certain toxic compounds (Brown, 1982).

Outbreaks have been fairly low which has been attributed to underreporting. The confirmed cases of outbreaks in the United States over a period of 5 years are as shown in Table 2.5. The typical symptoms of *Clostridium perfringens,* poisoning are usually abdominal pain, diarrhea, nausea and fever.

Table 2.5: Outbreaks, cases and deaths from *Clostridium perfringens,* food-borne gastroenteritis in the United States, 1983-1987 (Bean *et al.,* 1990).

Years	Outbreaks/Cases/Deaths
1983	5/353/0
1984	8/882/2
1985	6/1016/0
1986	3/202/0
1987	2/290/0

The microorganism is sensitive to cold temperatures (below 4°C) and food safety is therefore based largely on proper attention to time/temperature conditions of cooling and improvement of slaughter hygiene. It should be noted that dried spores can survive longer in frozen conditions (Brown, 1982; International Commission for Microbiological Safety of Foods (ICMSF), 1986; Smart *et al.,* 1979).

2.2.3 *Staphylococcus aureus*

This organism is a gram positive, facultative anaerobe. Its presence in food is usually associated with food handlers or mastitis in cows (NACMCF, 1993).

Approximately 40% of adults carry *Staphylococcus aureus* in the nose and throat and 15% on the skin, especially around the hands. Therefore coughs and sneezes may carry droplet infection which can easily spread not only to the environment but also to the food being handled. However, the two most important sources of contamination to foods are nasal carriers and individuals whose arms and hands are inflicted with boils and carbuncles and are permitted to handle foods (Sprenger, 1995; Troller, 1976).

The symptoms of staphylococcus food poisoning usually develop within 4 hours of ingestion of contaminated food and the symptoms include nausea, vomiting, abdominal cramps, diarrhea, sweating, headache, prostration and sometimes a fall in body temperature (Sprenger, 1995). Although the disease caused by this organism is characterized by low mortality and relatively short duration, the frequency of poisoning and the severity of the symptoms mark *Staphylococcal aureus* food poisoning as an important food-borne disease. The six leading foods, which have been associated with the incidence of Staphylococcal outbreaks, are indicated in Table 2.6.

Table 2.6: Leading food sources for staphylococcal gastroenteritis outbreaks in the United States, 1973-1987 (Bean & Griffin, 1990).

Food source	Number of Outbreaks
Pork	96
Bakery products	26
Beef	22
Turkey	20
Chicken	14
Eggs	9

However, with regard to general food vehicles, outbreaks have been reported in the United States from 1973 to 1987 (Table 2.7). With notable improvement in the good manufacturing practices in the United States the disease outbreak dropped from 16% in 1983 to 1% in 1987 of all the reported cases of outbreaks of food-borne diseases. Unfortunately in South Africa *Staphylococcus aureus* is still a major problem to contend with in the meat industry (Voster *et al.,* 1994).

Table 2.7: Staphylococcal food-borne gastroenteritis outbreaks and cases in the United States, 1973-1987 (Bean & Grifffin, 1990; Bean *et al.,* 1990).

Years	Outbreaks	Cases	Percentage of all cases
1973-1987	367	17248	14.0
1983	14	1257	15.9
1984	11	1153	14.1
1985	14	421	1.8
1986	7	250	4.3
1987	1	100	1.0

Studies done by Bean & Griffin (1990), indicated that the main factors that usually lead to the outbreak of staphylococcal food-borne gastroenteritis are usually due to temperature abuse of the products, poor hygiene amongst personnel and within the establishments and consumer associated problems as indicated in Table 2.8.

Table 2.8: Leading factors that led to the outbreaks of staphylococcal food-borne gastroenteritis in the United States, 1973-1987 (Bean & Griffin, 1990).

Causes	Number of Outbreaks
Improper holding temperature	98
Poor personal hygiene	71
Contaminated equipment	43
Inadequate cooking	22
Food from unsafe source	12
Others	24

Control of this pathogen can be achieved by (Sprenger, 1995; Troller, 1976):

- Removal of the microorganism physically for example by trimming of carcasses,
- aesepsis which is the provision of the first line of defence by focusing on the human element who harbour and transfer this organism directly or indirectly to foods through careless acts and allowing conditions to exist in which the pathogen can proliferate,
- Temperature-time control which invariably prevents or delays growth and toxin production and finally,
- Killing of the microorganism using bactericides.

2.2.4 *Listeria monocytogenes*

Listeria monocytogenes, is a gram positive, psychrotrophic bacillus. It is found mainly in soil, water, air or the intestinal tract. The incidence of *Listeria monocytogenes* is approximately 30-50% (or greater) in raw meat although levels are usually < 100 cfu/g. Interest in *Listeria* has increased because like *Yersinia* it is also capable of growth at refrigeration storage temperatures. The duration of storage may also give it extra time to grow to potentially dangerous levels. It has also been reported to be more pathogenic when grown at low temperatures as it produces a toxin (listeriolysin O). Control can be effected by implementation of a HACCP system (Farber, 1991; Sprenger, 1995).

2.3 MICROBIAL CONTAMINATION OF BEEF CARCASSES

The microbial profile of beef carcasses is dictated by events that occur during the conversion of the whole animal into carcass halves for further processing (Siragusa, Cutter, Dorsa & Koohmaraie, 1995). The incidence and levels of both pathogenic and spoilage microorganisms on the carcass can either be from intrinsic or extrinsic contamination. However, whether or not the load of intrinsic microorganisms associated with the living animal contribute a significant share of the contamination occurring in and on the carcass depends not only on the methods of handling but also on the defense mechanisms of the animal (Ayres, 1955; Nottingham, 1982). Generally, intrinsic contamination is limited as bactericidal activity continues at least for 1hour after death (Gill & Penney, 1979). This indicates that the main source of carcass contamination is usually from extrinsic contamination.

Sources of extrinsic contamination are:

- The slaughter stock
- Abattoir environment

2.3.1 Slaughter stock

The main source of microbial carcass contamination is usually from the slaughter stock. This is due to microorganisms present in the intestines or on the hide of the live animal. The live animals are often highly contaminated or asymptomatic carriers of pathogenic bacteria (Cray, Cassey, Boswath & Rasmussen, 1998; Hancock, Rice, Thomas, Dargatz & Besser, 1997; Lettelier, Messier & Quessy, 1999). Therefore any compromises made on the welfare and hygiene during pre-slaughter handling subsequently, affects the carcass hygiene (Ayres, 1955; Gregory, 1996; Sofos *et al.*, 1999a; Sofos *et al.*, 1999b).

The degree of carcass contamination depends a lot on the environmental conditions to which the live animal has been exposed to. These environmental conditions include climate, geographic location, husbandry conditions, method of transportation, holding conditions and animal feed (Cray *et al.,* 1998). For instance Smulders (1995) elaborated on the effects of husbandry indicating that intensive agriculture involves the rearing of young animals having immature gut flora and therefore lacking resistance to colonisation by pathogens. Other workers have also indicated the vulnerability of the younger animals. Sofos *et al.* (1999b) showed that they were much more prone to *Salmonella* contamination compared to the older bulls. Church & Wood (1992) also indicated that in cases where the animal was housed, the main microorganisms were those of intestinal origin, whereas animals raised on pastures tended to carry more bacteria of soil origin. However, irrespective of where the animal is raised it is important to prevent excess mud and dung accumulation on the animal. For example, Church & Wood (1992) showed that in housed animals as little as 3g of soil was required to contaminate a whole side of beef carcass with 10^5 microorganisms per 6.45 cm^2. A study done by Bell (1997) indicated that soiled hides coming into contact with the carcasses would typically give rise to the aerobic plate counts and *Escherichia coli* counts of approximately log 5.13 and log 3.90 respectively. A recent study by Sofos *et al.* (1999a) also determined that the larger the amounts of mud on the hide of steers and heifers the higher the incidence of *Salmonella*.

The most stressful environmental condition occurs during transportation and during the holding period in the lairage at the abattoir. These areas have been identified as potential critical control points in the slaughter lines (Kapsrowiak & Hechelmann, 1992). During transportation dispatched animals should not have full paunches, otherwise it becomes very difficult to avoid the spread of faecal contamination. It has been noted that any undue stress caused to the animal during transport or at the lairage can lead to increased spread of *Salmonella* from infected animals to uninfected animals (Church & Wood, 1992; Cray *et al.*, 1998; Herriot, Hancock, Ebel, Carpenter, Rice & Besser, 1998). The amount of time the animal spends at the lairage and the sanitary conditions of the lairages are also important as lack of proper care at the lairage can lead to heavy soiling of the animals' hides. This can provide a major source of bacterial contamination during slaughtering operations as was indicated by Sofos *et al.* (1999a). Smulders (1995) consequently showed that the farm environment and transportation permits a recycling of excreted pathogens as a result of which livestock are trapped in a vicious cycle of infection, excretion and re-infection due to insufficient preventive measures.

2.3.2 Abattoir environment

The abattoir environment as defined by the Public Health Regulations of South Africa is composed of the plant and equipment, personnel, cleaning and sanitation and slaughtering and processing of animals (Meat and meat products hygiene act. 1967-act no. 87 of 1967). For any processing to be carried out the abattoir must comply with the stated regulation. Figure 2.2 gives an overview of a typical slaughterhouse. This is essential as the interacting environmental factors and the processing methods employed play a large role in fixing the distribution or adding to the microbes brought in by the animal and also determine the hygienic state of the slaughterhouse. In the slaughterhouse the condition of the carcasses immediately after slaughter is usually a good index of hygiene (Church & Wood, 1992).

2.3.2.1 *Plant and equipment*

Within the abattoir environment, attention must be paid to the functional design, layout and management of the slaughterhouse. The layout of the carcass transport lines for the slaughter, skinning, evisceration and chilling steps will influence the contamination of carcasses. The product flow is especially important in an abattoir, because subsequent steps usually carry less pathogens. Within the product flow the skin, offals and personnel carry a large number of pathogens which can easily be distributed and redistributed (ICMSF, 1988; South African Bureau of Standards (SABS) 049,1989).

Segregation of clean from dirty operations is also vital, as it will reduce cross contamination of carcasses by splashing. The physical separation of these areas also restricts access of transport to and from the areas and hence reduces any chances of cross contamination by personnel. Any equipment to be shared by the sections must also be sterilized to ensure that it is not a source of contamination. Equipment for butchering meat is difficult to operate in a consistently hygienic manner because of continual recontamination by incoming raw materials, the build up of meat residues often containing growing number of bacteria and the risk of cross-contamination between more or less contaminated meats. Good design of equipment and satisfactory finishing of contact surfaces is essential, as it will permit easy and effective cleaning. The design must avoid dead spaces where products can accumulate and not be removed by routine cleaning (Brown & Baird Parker, 1982). It should also ensure that the equipment sterilisers are available and maintained at a temperature of 82.2 ^{0}C.

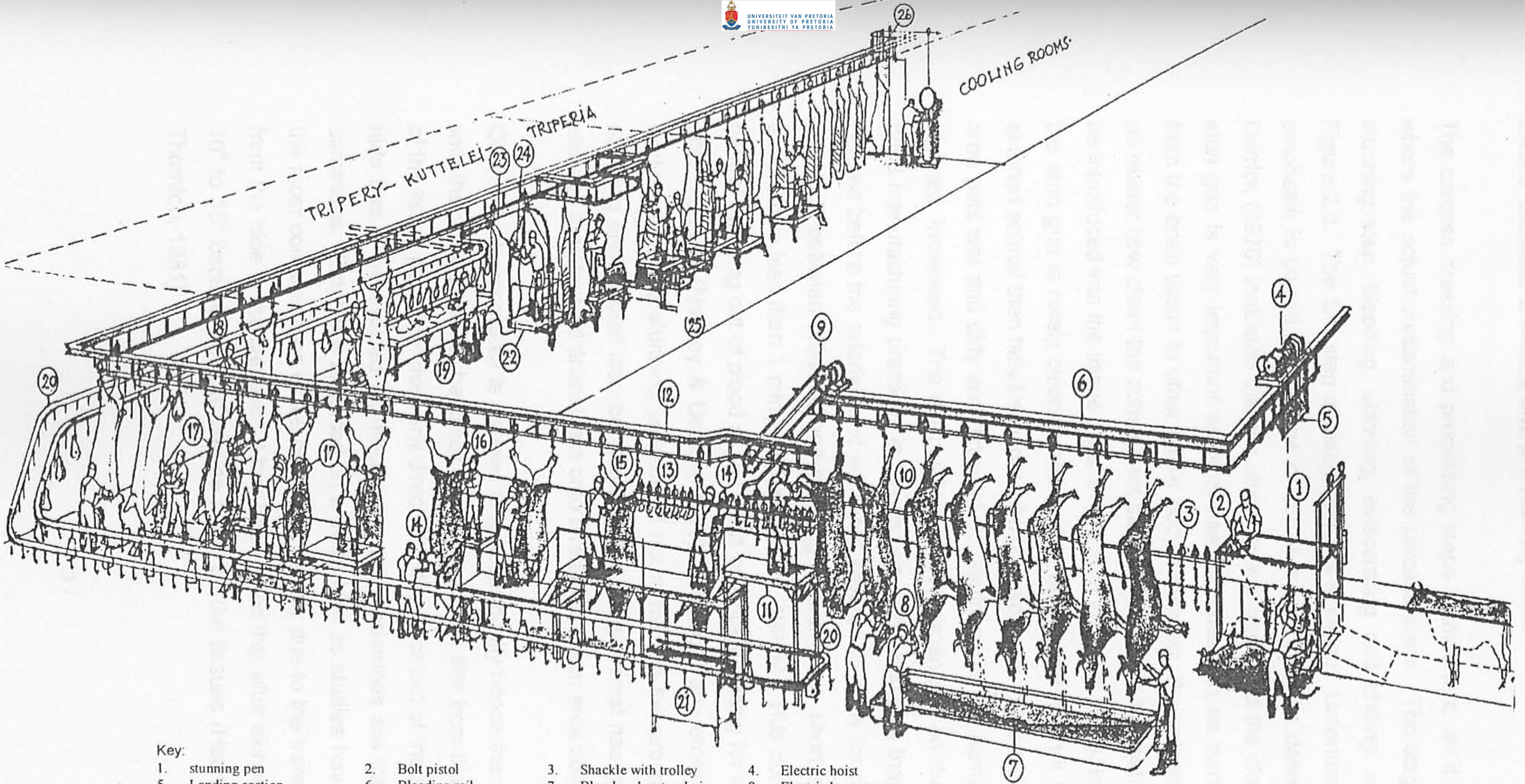
In addition, to the functional design and plant equipment other support structures, which form the foundation of the plant installation, like proximity to potential sources of contamination; sufficiency and quality of water supply; wastewater removal;

adequacy of power supply and availability of transportation must be considered (ICMSF, 1988; SABS 049,1989). This is important as micro-flora of processing plants can gain entry from the air, water, pests, people, dirt and equipment in addition, to those that gain entry through the raw material. The design of the plant can effectively restrict entry of pests, such as flies, rodents, birds, cats and dogs. They mainly contaminate meat with microorganisms by transferring microorganisms from one source to the next or from their droppings. Other factors such as equipping plant entries and exits with suitable barriers; fitting windows with appropriate screens to keep out insects, fitting air intakes with screens and filters for dust and appropriate environmental hygiene measures must also run hand in hand.

2.3.2.2 *Personnel*

Health and hygiene of personnel is one of the factors, which determine the type, and quantity of pathogenic microorganisms transmitted to man from food. The Health of the worker is important as man harbours various pathogens and transmission can occur under various conditions; including during the incubation period prior to clinical manifestation of a disease. The incubation stage is of concern due to lack of discernible illness yet the individual is shedding pathogens (Sprenger, 1995). It has been shown that during acute illness a person suffering from acute salmonellosis may shed as many as 10^9cells/g of feaces. Purulent skin infections are often laden with *Staphylococcus aureus,* which are readily transferred to foods when infected persons handle foods. Hence persons ill with diarrhea, vomiting, colds or infected skin lesions should not handle foods. In addition, to the inherent microbes on the personnel, it has also been demonstrated that the hands of workers in the meat industry have more coliform bacteria and *Salmonella* than hands of workers in other food sectors. This is obviously due to extensive contact with products of animal origin (De Wit & Kampelmacher, 1982). Personnel must therefore wash their hands properly after any break, periodically while at the processing line, on change of job functions and after handling contaminated materials or objects.

The hygienic habits of the workers plays a significant role in the control of contamination. The habits are encompassed under basic good manufacturing practices and range from basic clothing to hand washing and other processing steps and these factors all impact on each other. For instance, the clothing of workers must be clean, neat and without adornments. Uniforms have been noted to be an excellent means of controlling neatness and have a powerful psychological impact on workers attitudes towards good sanitation. In addition, strategic placement of facilities to ensure that they cannot be ignored is important. Such facilities include hand washing facilities and processing equipment, which ultimately play a role in maintenance of product flow (Nortjé & Van Holy, 1985). Studies carried out by the World Health Organization/Food and Agricultural Organization (WHO/FAO) (1983) concluded that routine health examinations is not useful as a control measure but education of food handlers, strict supervision and control of food hygiene offered a more effective alternative strategy. Thus, it is very important that the slaughter process follows proper sanitary guidelines at all times with emphasis on personnel health, general appearance; personal conduct, training and housekeeping practices (Bell, 1997; Samarco, Ripabelli, Ruberto, Iannitto & Grasso, 1997; Sierra, Gonzalez-Fandos, Garcia-Lopez, Fernandez & Prieto, 1995; Sprenger, 1995; Wood *et al.*, 1998).



Key:

1. stunning pen
2. Bolt pistol
3. Shackle with trolley
4. Electric hoist
5. Landing section
6. Bleeding rail
7. Blood and water drain
8. Electric horn saw
9. Declined conveyor
10. Shackle return rail
11. Transfering platform
12. Dressing rail
13. Trolley hooks
14. Electric feet saw
15. Aitch bone cutter
16. Tail puller
17. Pneumatic dehidingknife
18. Brisket saw
19. Viscera inspection table
20. Head conveyor
21. Head flushing cabinet
22. Elevating platform
23. Pneumatic spreader
24. Electric splitting saw
25. High pressure washer
26. Overhead track scale

Figure 2.2: Layout of a cattle slaughter house (Atlas Danmark)

2.3.2.3 *Carcass dressing and processing steps*

The carcass dressing and processing steps is important, as it is at this level where the actual contamination of the carcass starts. The stages include the stunning step, bleeding, skinning, eviscerating and chilling as illustrated in Figure 2.3. The first step of slaughtering is stunning. Unfortunately, very little emphasis is placed on hygiene of the stun gun. Studies done by Mackay & Derrick (1979) indicated that the stunning technique and the cleanliness of the stun gun is very important as otherwise microbes can be transferred directly from the brain tissue to other edible body organs viz. the spleen. Implying that no matter how clean the subsequent slaughtering steps are, pathogens can still be introduced into the tissue organs right from the initial stage. In most abattoirs the stun gun is rarely cleaned and is only maintained when it backfires. The stunned animal then falls freely onto the floor adjacent to the stunning bay. The area gets wet and dirty and dirt build up continues as the numbers of animals stunned, increased. The dirt build up is also dependent on the adherence to good manufacturing practices in the section. The animal is then shackled and hanged before the arteries and veins are severed to allow for proper bleeding. The time between stunning and bleeding should be as short as possible and should take less than 1 minute (Hechelmann, 1995b). This duration allows for natural pumping out of blood as the heart continues beating for about 3 minutes after stunning (Mackey & Derrick, 1979). To avoid any cross contamination, workers from the stunning bay should not move into the processing hall. The stunning area should also be cleaned after every animal has been bled. This ensures that the next animal falls onto a relatively clean area devoid of soil.

Often the stunning area is cleaned only occasionally hence the hide on contact with the ground usually becomes impregnated with filth from the walls and floor of the killing pen. Therefore any direct or indirect contact of the carcass with the hide has to be avoided as otherwise a lot of microbes are transferred to the carcasses. Emphasis is placed on a clean hide as studies have indicated that the most contamination of the carcass is usually due to the transfer of microbes from the hide to the carcass. It has been noted that after skinning, as many as 10^4 to 10^6 bacteria per cm^2 can be found on the tissues (Hechelmann, 1995b; Thornton, 1981)

The gastrointestinal and respiratory tracts of live animals have also been implicated in contamination of the carcasses (Ayres, 1955; Bell, 1997; Roberts *et al.*, 1984). Pathogenic bacteria, which can contaminate carcasses during slaughter and dressing, inhabit the gastrointestinal tract. The transfer of these pathogens to the carcasses mainly occurs when the intestinal tract is punctured accidentally, consequently spilling the gut contents onto the dressed meats. This emphasises the need for not only good hygienic practices but also good slaughtering techniques in an abattoir (Nortjé & Naude, 1981). Incidences of contamination associated with respiratory tracts have decreased due to the suspending of the stunned animal hence, the mucus is released outwards (Ayres, 1955; Church & Wood, 1992).

In the evisceration step, intact viscera present little hazard but leakage from the gastrointestinal tract could cause widespread contamination (Church & Wood, 1992). The pathogens introduced onto the carcass are mainly those associated with faecal matter (Bell, 1997). Contamination during the slaughter operations of carcass skinning and evisceration can also occur by the introduction of the pathogens onto the meat surfaces via personnel hands, saws, equipment and clothing (Dickson & Anderson, 1992; Selgas, Marin, Pin & Cassas, 1993; Sierra, *et al.,* 1995).

At the completion of dressing, the warm (30-40°C) and wet carcass surface is ideal for the proliferation of pathogens and spoilage microorganisms (Church & Wood, 1992). The carcass surface must therefore be cooled to 7°C or below to minimize microbial growth before it becomes a hazard. Various researchers (Cox, 1989; Farber, 1991; Palumbo, 1986) have also reviewed the possibility of growth of emerging pathogens at the chilling stage. Temperature control and monitoring in an abattoir is therefore very important, as it is the final stage at which control can be effected (Figure 2.3). However, cooling too rapidly must also be avoided as otherwise cold shortening (toughening) of the muscle can occur (Church & Wood, 1992; Kapsrowiak & Hechelmann, 1992).

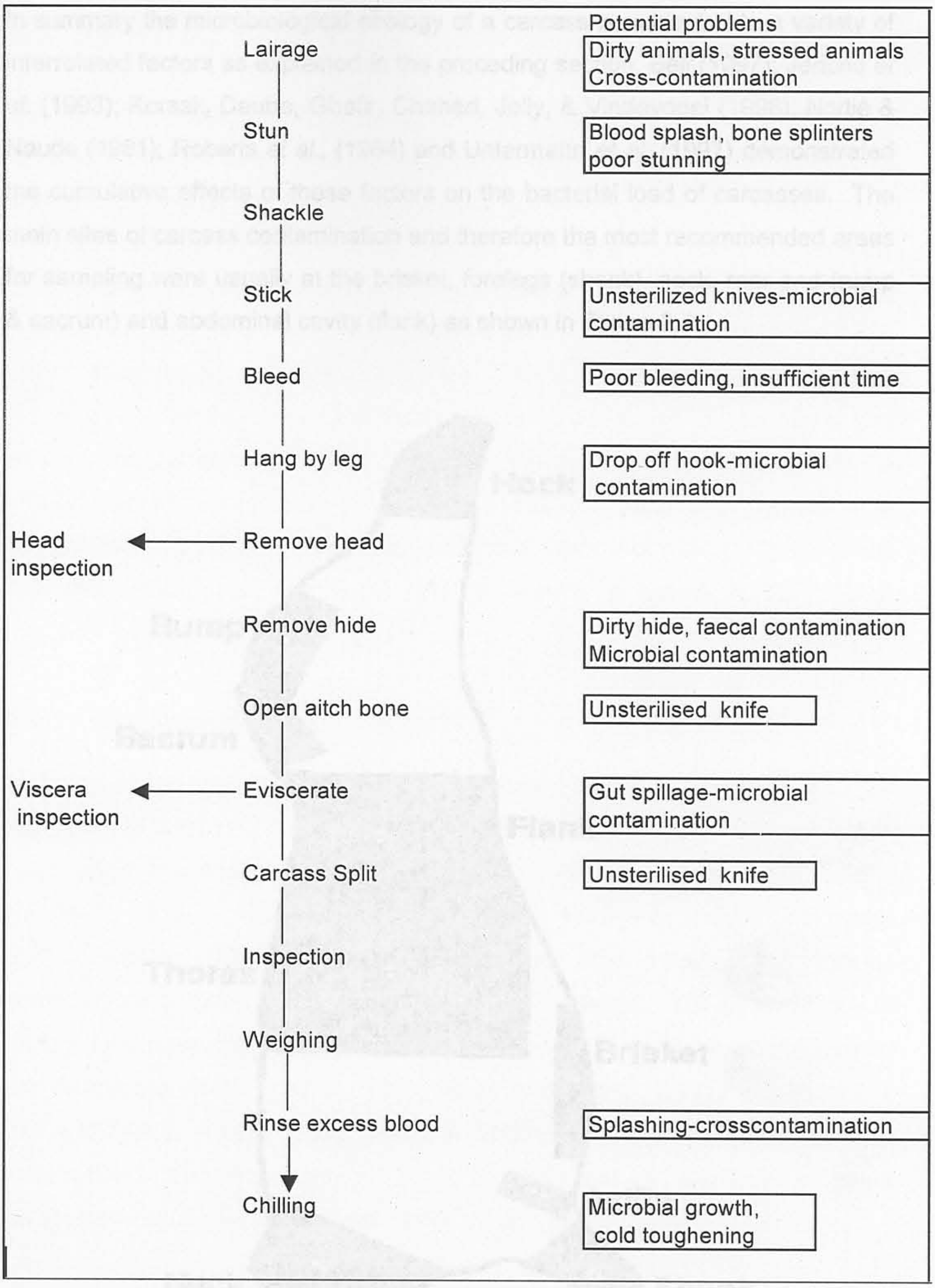


Figure 2.3: Typical cattle slaughter line and potential problems (adapted from: Church and Wood, 1992).

In summary the microbiological ecology of a carcass is subjected to a variety of interrelated factors as explained in the preceding section. Bell (1997); Jericho *et al.* (1993); Korsak, Daube, Ghafir, Chahed, Jolly, & Vindevogel (1998); Nortjé & Naude (1981); Roberts *et al.*, (1984) and Untermann *et al.* (1997) demonstrated the cumulative effects of these factors on the bacterial load of carcasses. The main sites of carcass contamination and therefore the most recommended areas for sampling were usually at the brisket, forelegs (shank), neck, rear end (rump & sacrum) and abdominal cavity (flank) as shown in Figure 2.4.

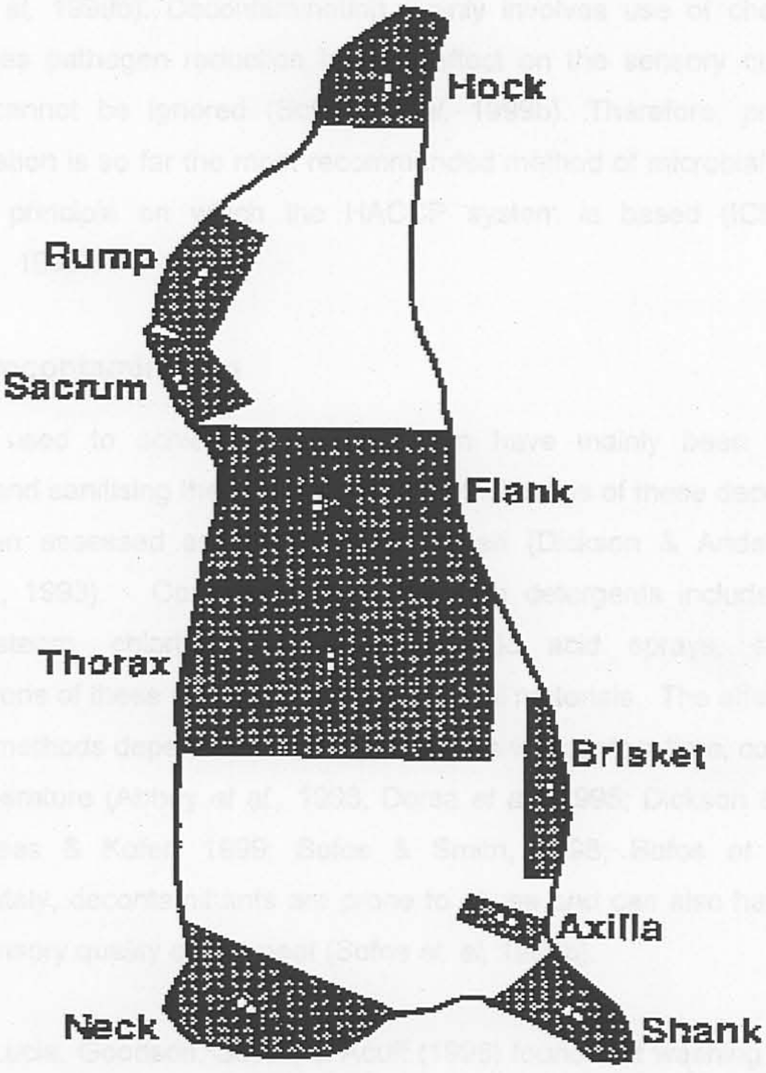


Figure 2.4: Lateral view of beef carcass depicting potential contamination points (adapted from: Jericho *et al.*, 1993).

2.4 MICROBIAL CONTROL

Elimination or reduction of microbial levels in meat has received considerable attention in recent years and the problem of reducing the number of bacteria from the carcasses has been approached in a variety of ways. The focus of microbial control by the various workers has been on either preventing contamination or decontaminating the carcasses (Abbey, Randall, Riemann, Kotrola, Wilson, Boyer & Brown, 1998; Dickson & Anderson, 1992; Dorsa, Cutter, Siragusa & Koohmarie, 1995; Pless & Kofer, 1999; Sofos & Smith, 1998; Sofos *et al,* 1999b). Decontamination mainly involves use of chemicals and emphasises pathogen reduction but the effect on the sensory quality of the product cannot be ignored (Sofos *et. al,* 1999b). Therefore, prevention of contamination is so far the most recommended method of microbial control and it is the principle on which the HACCP system is based (ICMSF, 1988; NACMCF, 1993).

2.4.1 Decontamination

Methods used to achieve decontamination have mainly been focused on washing and sanitising the carcasses. The efficiencies of these decontaminants have been assessed separately or combined (Dickson & Anderson, 1992; NACMCF, 1993). Commonly used sanitizing detergents include; hot water (82°C), steam, chlorine, short-chain organic acid sprays, and various combinations of these and approved bactericidal materials. The effectiveness of all these methods depend on a variety of factors viz. contact time, concentration, and temperature (Abbey *et al.,* 1998; Dorsa *et al.,* 1995; Dickson & Anderson, 1992; Pless & Kofer, 1999; Sofos & Smith, 1998; Sofos *et al,* 1999b). Unfortunately, decontaminants are prone to abuse and can also have an effect on the sensory quality of the meat (Sofos *et. al,* 1999b).

Castillo, Lucia, Goodson, Savell, & Acuff (1998) found that washing the carcass surface with hot water at 95°C brought about significant reductions on the microbial levels. They suggested that it could be used as a CCP in a HACCP system. However, this method has it flaws as shown by earlier studies carried out on hot water washing by Dorsa *et al.* (1995). They indicated that despite the positive achievements of the reduction in microbial levels, the hot water wash extended hydration of the carcass and therefore protected a limited number of bacterial populations.

Various researchers have also reviewed the use of disinfectant solutions. Delazari, Iaria, Riemann, Cliver & Mori (1998) found that the efficacy of chemicals was dependent on the type of exposed tissue, lean or fat and the type of microorganism. Smulders and Greer (1998) further corroborated this by showing that some meat pathogens are sensitive to organic acids (e.g. *Yersinia enterocolitica*) while others are resistant to it (e.g. *E. coli*). The suggestion that the disinfectants are bacterium specific may also indicate that the choice of disinfectant used should ideally be broad spectrum and be able to act in any tissue type. It is also necessary to avoid reduced competition due to selective disinfection in the niche leading to dormant bacteria expressing themselves (Sprenger, 1995). Unfortunately, most of the broad-based disinfectants cannot be used on food products.

Dickson & Anderson (1992) reviewed works by various researchers on carcass decontamination by washing and sanitising systems. In all the systems production of pathogen free meat could not be guaranteed and the safety of the products still depended a great deal on good manufacturing practices. Smulders & Greer (1998) added that use of decontaminants could easily be abused and used as a means of concealing poor hygiene. But more important is the fact that these methods can only reduce the initial levels of bacteria and there is no control over future re-contamination of the product. This can even be in cases where such problems could otherwise have been prevented or avoided through proper design, processing techniques and good manufacturing practices (ICMCF, 1988; NACMCF, 1993; Pless & Kofer, 1999).

Van Netten, Valentijn, Mossel, & Huis In 'T Veld (1997) indicated that HACCP is a prerequisite for ultimately rendering meat carcass surfaces free of pathogens no matter what decontamination method was used. Therefore, various carcass intervention procedures such as washing, sanitizing agents and pasteurization can only be used as an adjunct to HACCP. These methods would therefore be used only to improve the bacterial condition of the carcass by intervention at specific points in the process (Dorsa *et al.,* 1995; Gorman, Morgan, Sofos & Smith, 1995; Gorman, Sofos, Morgan, Schmidt & Smith, 1995; Prasai, Acuff, Lucia, Hale, Savell, Morgan, 1991; Siragusa *et al.* 1995). Other schools of thought also indicate that the decontamination of the carcass is not useful due to recontamination and growth during further processing (Smulders & Greer, 1998; Sofos & Smith, 1998). In addition, use of the decontaminants are also subject to several factors, including safety, product quality, efficacy, adaptability, need for decontamination and cost (Sofos & Smith, 1998).

2.4.2 Application of HACCP

The modern approach to abattoir contamination control relies on the HACCP system. The HACCP system provides the most effective means for minimizing microbial contamination on meat carcasses, thus reducing the risk of food-borne illness in humans (Bolton, Oser, Cocoma, Palumbo & Miller, 1999; Cross, 1996; Karr, Maretzki & Knabel, 1994; NACMCF, 1993; Yataro, Yutaka, Kimikazu & Tsutomu, 1999). Over the years researchers have noted that improvement of slaughtering techniques went a long way in controlling microbial levels better than use of decontaminants (Hechelmann, 1995a; Pless & Kofer, 1999; Sofos & Smith, 1998). This is especially important as the introduction of a HACCP programme adopts working patterns in which the processing techniques, design of the plant, flow of the product and personnel are all taken into consideration. With HACCP the main improvement of the microbial levels is achieved by identifying potential risk areas and the points are then monitored (ICMSF, 1988). In the case of abattoirs, monitoring mainly involves visual inspection to ensure that the slaughtering techniques are executed correctly and the product is well chilled. A study carried out by Bolton *et al.,* (1999) indicated that visual monitoring managed to reduce carcass contamination levels from approximately 8% to 1% over a period of 4 years with total aerobic counts falling by 99.8%.

2.4.2.1 *HACCP control measures*

HACCP control measures are any actions and activities that can be used to prevent or eliminate a food safety hazard or reduce it to an acceptable level. The method of control is determined by risk analysis and depends to a great extent on the epidemiological data of the food-borne diseases of the specific food (refer 2.1). Before the control is effected the potential problematic areas have to be identified from the process flow chart. Figure 2.5 gives a general overview of the sites of contamination and the causes of contamination along the meat processing line from the live animal to the chilled carcass. It also shows the points at which control can be effected within the beef slaughter and dressing process. This includes the carcass skinning, evisceration and chilling points (Kasprowiak & Hechelmann, 1992).

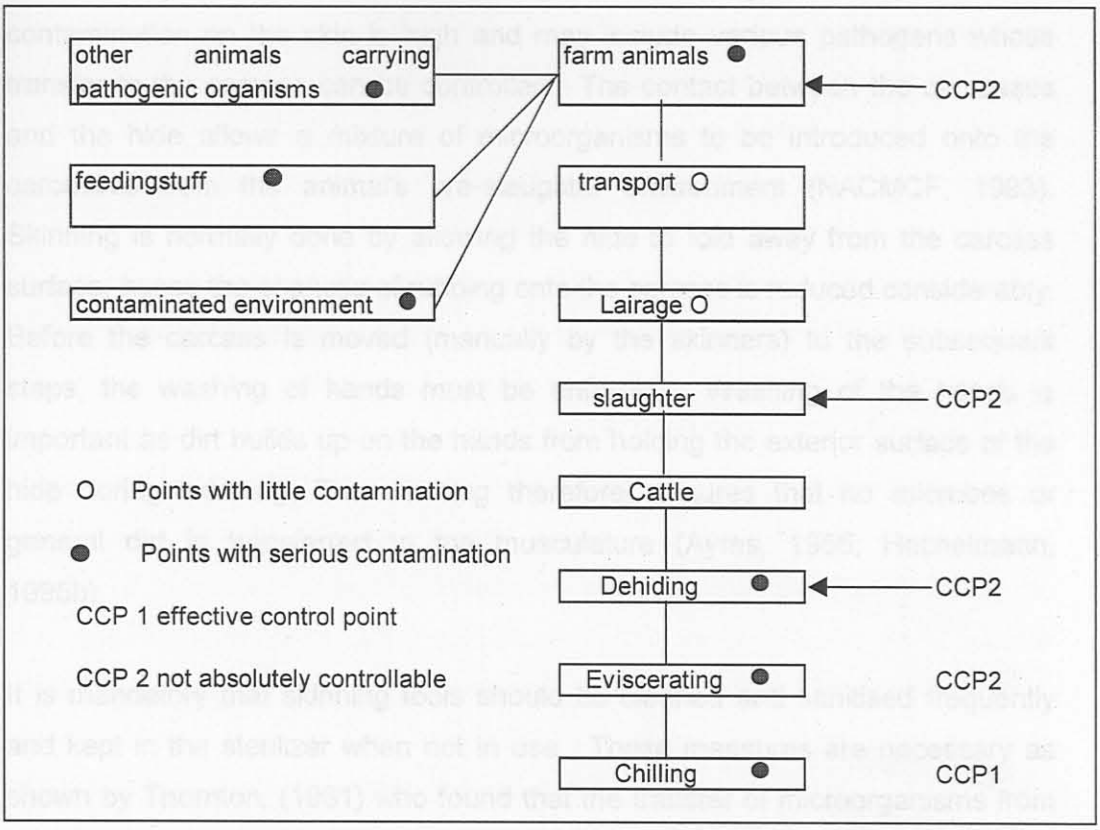


Figure 2.5: Causes of contamination and critical control points before and during the slaughter of cattle (adapted from: Kasprowiak & Hechelmann, 1992).

Control of microbiological hazards in an abattoir is usually carried out by:

- Temperature/time control of the chill room that can reduce levels of microbial growth;
- Strict adherence to the cleaning and sanitation programs, which can eliminate or reduce the levels of microbiological contamination;
- Personnel and hygienic practices, which can reduce the levels of microbiological contamination.

The processing should aim to ensure that each of the stages should be "cleaner" than the one before it and contamination from the previous process must be avoided as much as possible (Bolton *et al.*, 1999).

2.4.2.1.1 Skinning

The skinning operation is considered as a critical control point because microbial contamination on the skin is high and may include various pathogens whose transfer to the carcass can be controlled. The contact between the carcasses and the hide allows a mixture of microorganisms to be introduced onto the carcasses from the animal's pre-slaughter environment (NACMCF, 1993). Skinning is normally done by allowing the hide to fold away from the carcass surface, hence the chances of rubbing onto the carcass is reduced considerably. Before the carcass is moved (manually by the skinners) to the subsequent steps, the washing of hands must be enforced. Washing of the hands is important as dirt builds up on the hands from holding the exterior surface of the hide during skinning. The washing therefore, ensures that no microbes or general dirt is transferred to the musculature (Ayres, 1955; Hechelmann, 1995b).

It is mandatory that skinning tools should be cleaned and sanitised frequently and kept in the sterilizer when not in use. These measures are necessary as shown by Thornton, (1981) who found that the transfer of microorganisms from the hide to the underlying tissues begins at the point of initial incision through the hide. The study indicated that this point tends to have the highest number of microorganisms with decreasing levels noted on the areas furthest removed from this region. Studies have shown that, either the blade, or contact of the carcass with loose skin, or personnel habits transfer these microbes (Ayres, 1955; Hechelmann, 1995b; Ridell & Korkella, 1993; Mackey & Derrick, 1979).

2.4.2.1.2 Evisceration

The process of evisceration is carried out as follows: the breastbone and the aitchbone are sawed through exposing thoracic, abdominal and pelvic cavities. The viscera is then loosened and removed in one continuous operation. Puncturing of the gastrointestinal tract by the knives leading to spilling of the gut contents on the abdominal cavity must be avoided. The evisceration step therefore also forms a very important control point in a HACCP program.

The carcass is then split into two halves, inspected and chilled (Hechelmann, 1995b).

2.4.2.1.3 Chilling

The chilling stage forms the final process at which control can be exercised in an abattoir. The step consists of lowering the carcass temperature below 10 °C and keeping it near 0 °C. Care must be taken to ensure that the chilled carcass temperature is at least below 10°C within a period of 24 hours. This method inhibits the growth of most pathogens causing food-borne diseases. For instance lowering the temperature to about 20 °C suppresses the growth rate of *Clostridium perfringens,* to levels were it is almost insignificant under practical conditions but total inhibition of growth is attained at 6.5 °C. In the case of *Salmonella* and *Staphylococcus aureus* growth is inhibited at 5.2 °C and 6.7 °C respectively. It should be noted that chilling does not kill microbes therefore the raw material must be of sound quality, cooled soon after inspection to prevent growth of mesophiles and ensure that there is minimal handling of the carcasses. Maintenance of the cold chain should continue up to the consumer level. Within the chill room the carcasses should be kept from touching each other to allow for proper airflow and avoid any chances of cross contamination (ICMSF, 1988; NACMCF, 1993; Rosset, 1982).

In conclusion proper control and monitoring of these critical control points are essential to avoid any transfer of microorganisms to the carcasses as illustrated in Table 2.9. In its entirety, improvement of slaughtering techniques can therefore be relied upon to achieve better microbial controls on the slaughter line. However, even with HACCP, zero tolerance in an abattoir is not practical and cannot be attained (NACMCF, 1993).

Table 2.9: Generic HACCP plan: Critical Control Points for Beef Slaughter (NACMCF, 1993).

Process/step	CCP	Critical limits	Monitoring procedure/frequency	Corrective action	Records	Verification
Skinning	CCP 1	≤20% of carcasses with dressing defects	Operator observes effectiveness of skinning process for each carcass. Visual analysis conducted under adequate lighting	Add operators Reduce chain speed Conduct carcass trimming	Random post - skinning carcass examination	Examination of random carcasses after skinning is complete using sampling plan sufficient to assure process control Survey of review records Initially conduct microbiological analysis for aerobic mesophiles and/or enterobactericiae to establish baseline data on expected bacterial numbers. Periodic follow up analysis to verify process control Review control charts to confirm that sampling frequency is sufficient to detect 20% defect criteria

Table 2.9: Generic HACCP plan: Critical Control Points for Beef Slaughter (NACMCF, 1993) continued.

Process/step	CCP	Critical limits	Monitoring procedure/frequency	Corrective action	Records	Verification
Evisceration	CCP	0% 0ccurence of the following defects for a single carcass: faecal material, ingesta, urine or abscesses		(1)Trained employee immediately trims defect area on carcass (2) Add operators (3) Reduce chain speed (4) sanitize soiled evisceration tools with 82.2 ° C water (5) sanitize soiled clothing with 48.9 ° C water or appropriate sanitizer	Random post-evisceration carcass examination	Supervisory review of records and operations Random examination of carcasses after evisceration using sampling plan sufficient to assure process control
Chill	CCP	Deep muscle (6in) temperature of 7 ° C within 36 h, reaching 10 ° C after the first 24h Carcass spaced a minimum of 1-2 in apart	Continual confirmation of environmental conditions (temperature) Monitor carcass spacing upon arrival to chill coolers Conduct random temperature monitoring of carcasses after appropriate chill time	Adjust carcass spacing Adjust chill cooler temperature Alert maintenance if cooler unit is not functioning properly Continue chilling carcasses until internal temperature reaches 10 ° C	Chill log	Supervisory review of records Review thermometer calibration Periodic monitoring of cooling rates of deep muscle tissue through the use of temperature recording devices

2.4.2.2 *Benefits of HACCP in the meat industry*

Benefits of HACCP in the meat industry are multifold and the benefits can be reaped across board. Primarily, it places the responsibility for ensuring food safety on the personnel. This is due to the well-organized and documented plan, which comes with a HACCP system. A HACCP system also consistently ensures safe food production. By assuring safety during processing with a HACCP system, the resources expended on the finished products can be devoted to process control and optimizing the process. In addition, to safe production of food, the effective monitoring of CCP's can lift the whole operation hence ensuring improved quality (Stier & Blumenthal, 1995). Perceived sense of enhanced safety and quality always follows from the management to the workers. This is normally a result of enhanced understanding of the operation or increased worker involvement, which are inherent features of a HACCP system. This leads to process optimization as employee morale is boosted, leading to greater efficiencies as the personnel feel they are part of the program (Stier & Blumenthal, 1995).

Secondly, in operations like abattoirs which are mainly supplier or producer oriented, a HACCP system makes them more desirable trading partners due to assured safe and quality products. Implementation of a HACCP in one system within a food chain also always sparks a chain reaction, as the specific entity in question, expects the same standards to be maintained by his suppliers of raw materials and distributors of the completed product. Therefore as one link in the food chain adopts a particular quality management system its influence on other units cannot be overlooked. For instance expectations of adoption of a similar approach by the farm production unit would increase to ensure a steady supply of better animals (Gardner, 1997; Stier & Blumenthal, 1995).

Other factors like reduced product liability cannot be overlooked. Scarlett (1991) summarized the HACCP approach to product liability as follows; "to a food technologist HACCP is a food safety tool which has well developed methods for preventing mistakes from happening. To a lawyer, however, HACCP is a damage control procedure whereby the potential defendants in a multimillion-dollar lawsuit can try to minimize the possibility that their food product will be responsible for dozens, or even hundreds, of sick, very angry and extremely vengeful plaintiffs". Interviews conducted by Stier & Blumenthal (1995) amongst food processors indicated that HACCP could allow them to reduce insurance rates.

Finally, it has an added advantage as it permits more government oversight in food production. This places the producers in a position where they are part of a rule making process should regulations demand its implementation. For instance, a government investigator can easily determine and evaluate both current and past conditions that are critical to ensuring the safety of food. It may also assist food companies to compete effectively in the world market (Culler, 1997; Jouve, 1998).

2.5 SUMMARY

Previous and current data on epidemiology of food-borne illness associated with meat indicate that meatborne diseases are still part of the meat processing chain. This is inspite of the hygiene measures in place in most abattoirs and the various modern decontamination procedures currently available in the market. It is in light of this that this project was proposed.

The HACCP system gives a distinct possibility of reducing pathogens as previously confirmed in other food industries as it focuses on controlling entry of microorganisms into the product. The other inspection methods mainly focuses on removal of the microorganism, this is especially a difficult feat in the meat industry as a total microbial destruction step is not available.

2.6 OBJECTIVES

The main objective of the study was to determine the effect of HACCP implementation on the microbiological status of carcasses in a specific C-class abattoir.

The following specific objectives were formulated:

To determine the effect of HACCP implementation on aerobic plate counts, total coliforms counts, *Staphylococcus aureus* counts, *Escherichia coli* counts, *Clostridium perfringens,* counts and *Salmonella* presence or absence on bovine carcasses at critical control points on the slaughter line.

To determine the effect of chilling on aerobic plate counts, total coliforms counts, *Staphylococcus aureus* counts, *Escherichia coli* counts, *Clostridium perfringens,* counts and *Salmonella* presence or absence on bovine carcasses before and after HACCP implementation.