

Effect of post-slaughter handling during distribution on microbiological quality and safety of meat in the formal and informal sectors of South Africa: A review

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(Received 17 July 2015; Accepted 4 January 2017; First published online 24 March 2017)

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Abstract

Global reports on illnesses and deaths related to food consumption continue to raise concern in most countries. This has led to diligent efforts to improve the manner in which food is handled. Hygienic handling of carcasses after slaughter is critical in preventing contamination and ensuring meat safety in both formal and informal meat trading sectors. However, in the informal sector, regulations as prescribed in the Meat Safety Act No. 40 of 2000, which have been set to protect consumer health, are not always adhered to. Although these regulations are put into practice in the formal sector, meat safety challenges associated with meat handling during distribution continue to raise concern. The distribution stage is the most critical period, during which the quality of meat can easily be compromised. Furthermore, meat inspection at the abattoir covers only visual assessment, without considering microbiological tests. Meeting food safety requirements set by government regulations remains a challenge to almost all food processors. This paper reviews the impact of post-slaughter handling on carcass quality and its implications for meat safety during the distribution stage in the formal and informal sectors in South Africa. It also details how meat handling in the informal meat trade exposes consumers to high health risks and recommends that governments create legislation that would be applicable to carcasses produced in the informal sector to align this sector with the regulations governing food production.

Keywords: Bacterial contamination, informal meat trade, legal requirements, meat handling, meat safety

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Introduction

In spite of the controls that have been put in place, food borne infections continue to be an immense problem, with millions of cases occurring annually throughout the world (Global Salm-Surv, 2003). In South Africa, illnesses and deaths related to food consumption continue to be reported. In addition to the misery caused, the financial loss associated with meat spoilage and illnesses is enormous. Recognition of pathogens before contaminated foods can be consumed is therefore crucial in protecting the public. Bryhni *et al.* (2002) stated that as time progresses, consumers would continue to demand meat of high-eating quality that is safer. Important traits associated with high-quality meat include an attractive colour, tenderness, juiciness and flavour intensity. In line with consumer demands, role players in the meat supply chain are encouraged to continue to find ways of delivering meat of high-eating quality that is safe for consumption. Mead (2004) highlighted that the microbiological safety and quality of meat are equally important to consumers, producers and retailers. The microbiological and technological qualities of meat depend on the physiological status of the animal at slaughter, the spread of contaminants during slaughter and processing, conditions of storage and, most importantly, the stages involved in the distribution of carcasses from the meat handlers to consumers (Adzitey & Huda, 2012).

In South Africa and other developing countries, the meat trade is divided into formal and informal sectors (Van Zyl *et al.*, 2008). The formal sector usually operates from abattoirs, and has meat inspectors who legally approve the meat for consumption. The meat is then distributed to retailers for consumers to purchase. This sector is governed by the Meat Safety Act No. 40 of 2000, which regulates meat and meat product distribution. Meat inspectors who approve meat for consumption usually perform visual inspection.

Guest Editor: J.B.J. Van Ryssen

No microbiological tests are performed at this stage. However, microbiological threats posed by pathogenic bacteria such as *campylobacter*, *salmonella* and *E. coli* cannot be detected adequately with the naked eye (Govender *et al.*, 2013).

Currently, the main cause of foodborne disease is microbiological; consequently, microbiological analysis plays a central role in quality control in the food sector. Two regulatory entities in South Africa are mainly responsible for managing safe meat production, processing and distribution, namely the Department of Agriculture, Forestry & Fisheries (DAFF) and the Department of Health (DoH) (Govender *et al.*, 2013). However, these public meat monitoring agents do not have a meat microbiological monitoring programme in place. According to the Meat Safety Act, the minister may establish a scheme for the improvement of meat safety. Therefore, a scheme that would provide hygiene assessment services for the improvement of meat safety, and would incorporate microbiological assessment of meat at the abattoir after slaughter and during marketing, is encouraged.

In the informal meat sector, non-inspected meat is distributed to the consumers and there are no regulations that govern operations. Adzitey *et al.* (2011a) stated that in most developing countries, especially in rural communities, standard and hygienic methods of handling and processing meats are given less attention, although they are part of the country's rules and regulations on animal and meat production. For instance, in most rural areas of Ghana, perhaps owing to constraints such as inadequate education, lack of potable water, and reliable power supplies, meat processing is traditionally carried out in unhygienic conditions (Adzitey *et al.*, 2011a). Moreover, slaughter methods are sometimes dictated by religious beliefs and local customs without inspection by qualified veterinary officers. Non-inspected meat may expose consumers to a higher food borne disease risk, which may lead to illness and death (Seeiso, 2009).

Meat is a perishable food and a health risk if handled improperly. Improper handling may result in the growth of foodborne bacterial pathogens which have been identified as major challenges to food safety. These micro-organisms may be pathogenic and may result in serious negative effects on human health. They include *Salmonella*, *Clostridium botulinum*, *Staphylococcus aureus*, *Clostridium perfringens*, *Bacillus cereus* and *Diarrheagenic Escherichia coli* (Hobbs & Roberts, 1993). A recent government-commissioned report on the South African meat inspection system estimated that the cost to the economy in medical, legal, other expenses, and absenteeism from work and school as a result of disease amounts to billions of rand annually. This report recommends a review of meat safety risk management systems and quality assurance practices (DoH, Department of Trade and Industry (DTI) & DAFF, 2013). Therefore, continuous efforts to improve food safety systems are encouraged.

Nowadays, research should focus on a farm-to-fork approach, in which the technological and microbiological quality of meat would be dealt with from the production to the consumption stage. This involves a number of processes, including the manner in which the animal was raised and transported, pre-slaughter logistics, slaughter in an abattoir, distribution, handling at purchasing points, and consumption. In all these stages, assurance of meat safety and quality are of paramount importance (McDonald & Sun, 1999), but for most consumers, quality goes beyond safety (Becker *et al.*, 2000). Most consumers have little knowledge of or information about the importance of food safety and consider only the appearance and associated perceived quality when making their purchasing decisions.

When meat is being distributed it goes through a number of channels during which its quality could easily be affected negatively. These challenges, which influence the technological and microbiological quality of meat are not well outlined in most studies. Most research has highlighted several pre-slaughter processes that affect meat eating quality at the farm (Ferguson & Warner, 2008; Grandin & Smith, 2000), during transportation of animals to the abattoir (Chulayo & Muchenje, 2013; Gajana *et al.*, 2013; Vimiso & Muchenje, 2013), the pre-slaughter period (Miranda-de la Lama *et al.*, 2009, Muchenje *et al.*, 2009; Muchenje & Ndou, 2012) and the slaughtering process (Muchenje *et al.*, 2009a; Miranda-de la Lama *et al.*, 2012; Njisane & Muchenje, 2013). Processes that occur after slaughter, which affect the quality of meat during distribution to retailers, are neglected, yet the distribution chain is considered the most important aspect in the meat industry because it includes critical stages that could affect meat quality before it reaches the shelves. Although some studies have focused on the microbiological quality of meat after slaughter (Gill *et al.*, 1996; Adzitey *et al.*, 2011a; Adzitey & Huda, 2012; Niyonzima *et al.*, 2013), post-slaughter factors affecting the technological and microbiological quality of meat during distribution in the formal and informal meat trade are not well outlined. This review, therefore, focuses on the way in which handling at various stages of the distribution chain affects carcass quality in the formal and informal meat trade in South Africa and its implications for meat safety and consumer health.

Post-slaughter carcass handling

Abattoirs are regulated by laws to ensure good standards of hygiene to prevent the spread of disease and to minimize needless animal cruelty (Grandin & Smith, 2000). The methods of slaughtering and handling

of carcasses play an important role in product quality and shelf-life of meat and meat products. Adzitey & Huda (2012) reported that poor carcass quality reflects in poorer meat quality. Meat quality has been identified as the most critical factor in a highly competitive meat industry in which its profit lies (Robles *et al.*, 2009). Most researchers define it based on conformational and functional qualities (Warriss, 2000; Muchenje *et al.*, 2008). Important technological meat quality attributes include colour, marbling, pH, tenderness, juiciness, and flavour (Bredahl *et al.*, 1998; Muchenje *et al.*, 2009). Should these be affected, profitability would also be influenced negatively (Grunert *et al.*, 2004).

Since consumers demand meat of high-eating quality, various approaches have been used to improve the quality of meat. These include the breeding aspect (Hermesch, 1997), nutritional and feeding strategy (Andersen *et al.*, 2005), and animal welfare during transportation (Appleby & Hughes, 1997) and at slaughter (Muchenje *et al.*, 2008). However, many post-slaughter practices contribute significantly to the quality of meat, which in turn affect profits, functional properties, eating qualities and the acceptance of the meat by consumers (Adzitey & Huda, 2012). These practices include the way in which the carcass is handled after slaughter, chilling, and other factors. Although some of these factors are being addressed, knowledge of those that influence meat quality at the distribution stage is scarce.

Post-slaughter carcass handling begins at the abattoir just after exsanguination and continues through to processing of meat, transportation to the market, and finally to consumers (Adzitey & Huda, 2012). Many irreversible quality losses, especially with regard to the hygienic quality, originate from improper slaughtering and carcass handling (FAO, 1990). Faulty meat handling, besides affecting the quality and shelf-life of meat and processed products, may endanger the health of consumers. Therefore, good hygiene during slaughtering and meat handling is of great importance for the quality of the final product because the higher the initial contamination, the faster the meat deterioration, especially under high ambient temperatures (NDA, 2007).

Carcasses are inspected after slaughter by qualified meat inspectors. Carcasses approved for consumption are then stamped as an indication that inspection has been done and that carcasses do not show signs of endangering the health of consumers. However, carcasses are approved in most South African abattoirs based on visual inspection, which considers factors such as bruising and assessment of major internal organs for signs of animal diseases. Microbiological assessment is seldom performed. The few abattoirs that perform microbial assessment do not do it as part of their daily assessment and the Department of Veterinary Public Health (DVPH) does it only monthly during audits. The guidelines used to assess the levels of contamination are based on European standards, and the supermarket chains that perform microbial assessment on their meat products use their own standards, for example Woolworths and Checkers. South African Meat Safety laws do not have their own national microbial standards. The European Union (EU) recommends that the levels of contamination by total aerobic bacteria and total coliforms do not exceed 5.0 and 2.5 log CFU/g, respectively (CE, 2005). These standards are based on European environmental temperatures, which may differ from the temperatures in other regions of the world. Hence, this review encourages research on microbial assessment to be done in abattoirs. This could aid the South African government to set up its own standards, which would be mandated for use in each abattoir and by each meat retailer.

Any carcass that is not approved for consumption after inspection is condemned, and does not enter the market (Adzitey & Huda, 2012). Condemnation may be partial or total, depending on the extent to which the meat has been affected. Huge economic losses have been experienced in the meat industry owing to the condemning of carcasses (Alton *et al.*, 2010).

Carcasses are then chilled at 4 °C for 24 hours in an abattoir to impair the development of rigor mortis and prevent the growth of micro-organisms (Brown *et al.*, 2009). The rate at which carcasses are chilled after slaughter influences meat quality. Speeding up the rate of chilling would help to reduce microbial growth on the carcass surface because the generation time for microorganisms increases at lower temperatures. Fast chilling also reduces evaporative weight loss, reduces the manifestation of pale soft exudative meat, and improves lean colour and water-holding capacity, all of which would have had negative effects on meat quality (Adzitey & Nurul, 2011). Furthermore, the rate at which temperature drops after slaughter influences enzyme activity, because this is temperature dependent (Adzitey & Nuda, 2012).

Meat distribution chains

The meat distribution chain is part of a longer supply chain that stretches from transportation of live animals to the abattoir to the final product at retail display. In the meat supply chain, livestock move from feedlots and farms to processors, who transform them into meat products and organise delivery to customers. This supply chain includes breeders, farmers, stockers and backgrounders, feedlot operators, packers, processors, food-service providers and retailers (Miranda-de la Lama *et al.*, 2014).

The main aim of distribution is the retention of an attractive, fresh appearance for the product, which will later be displayed, and the retardation of bacterial spoilage. Since meat is a highly perishable food (McDonald & Sun, 1999), some of the most important meat quality attributes can easily be affected during distribution to the supply points and growth of spoilage bacteria may occur. At the point of purchase, consumers use meat quality attributes such as colour, marbling, pH, tenderness, juiciness and flavour as their most important intrinsic quality cues to judge meat quality (Glitsch, 2000). Colour is probably the most important factor (Faustman & Cassens, 1990). After slaughter, the colour of meat depends on a principal pigment, myoglobin, which when mixed with oxygen becomes oxymyoglobin, and produces a bright red colour (Priolo *et al.*, 2001). Therefore during distribution the accumulation of air must be avoided as this pigment depends on the oxygen status of the environment. Nychas *et al.* (2008) stated that the risk potential, shelf-life and final quality of chilled products, processed and packed under good manufacturing practices and good hygiene practices, are determined by temperature conditions in the chilled distribution chain.

Stages affecting the technological and microbiological quality of meat

Richardson *et al.* (2009) stated that the supply chain that stretches from abattoir to final retail display is critical in meat quality. A number of factors affect meat quality in the supply chain, namely transportation (distance and temperature); type of packaging; storage (refrigeration and retention); display; and bacterial growth. These are critical factors that contribute significantly to meat quality and its shelf-life throughout the distribution chain (Rosenvold & Andersen, 2003). For consumers to purchase meat of high-eating quality, meat traders and handlers need to understand the factors that influence this quality.

Transportation and storage

Transportation is required throughout production, from the farm to delivery to consumers (Miranda-de Lama *et al.*, 2014). Transporting products to retail outlets and storage has been reported to be the weak link in the chain (Bsgb-Sorensen & Olsson, 1990). Before transportation, carcasses are chilled to prevent the growth of micro-organisms and to reduce meat deterioration prior to distribution. However, in some abattoirs, especially small throughput abattoirs, refrigeration may not be available and carcasses are transported without the initial chilling stage.

Poor handling of meat during transportation may result in a high rate of contamination and spoilage. When transporting meat, the challenge is to maintain proper refrigeration temperatures and keep the cold chain from breaking during steps such as palletization, staging, loading and unloading of containers, and in storage (Richardson *et al.*, 2009). The cold chain must not be interrupted as bacteria multiply rapidly in higher temperatures. The temperature and handling conditions stipulated in regulations must be strictly adhered to in all stages of the cold chain, through properly designed handling procedures in the chill storage rooms.

Temperature conditions in retail cabinets play a significant role in the final quality of the product. Temperature seems to be the most important factor that influences the spoilage and safety of meat (Koutsoumanis & Taoukis, 2005). Bacteria multiply more slowly when food is refrigerated, and freezing food can slow or even stop the spread of bacteria. Hence most bacteria are unable to proliferate or survive when exposed to low temperatures. Temperature affects not only the microbial condition of the meat, but also colour stability, with retail appearance being significantly affected by storage at 2 °C and 5 °C, compared with storage at below-zero temperatures (Jeremiah & Gibson, 2001). Zhao *et al.* (1994) stated that the most important factor for maintaining the red oxymyoglobin colour and keeping lipid oxidation to a minimum is the temperature. Therefore, different cooling rates affect oxidation or oxygenation of meat and thus change the colour of the meat surface.

Packaging

The shelf-life and quality of fresh meat are strongly influenced by initial meat quality, package parameters, and storage conditions (Zhao *et al.*, 1994). The logistical function of packaging serves mainly to protect the product during movement through distribution channels (Silayoi & Speece, 2007). Packaging plays an important role in the food industry because it helps to protect the product against environmental effects, communicates with consumers as a marketing tool, and provides them with ease of use and time-saving convenience (Yam *et al.*, 2005).

According to Brody (1997), packaging fresh meat is carried out to avoid contamination, delay spoilage, permit some enzymatic activity to improve tenderness, reduce weight loss and, where applicable, ensure an oxymyoglobin or cherry red colour in red meat at retail and customer level. However, the initial quality of the meat has to be good because packaging can only maintain the existing quality of the meat or delay the onset of spoilage by controlling the factors that contribute to it.

Package design and construction play significant roles in determining the shelf-life of a food product. The right selection of packaging materials and technologies maintains product quality and freshness during distribution and storage. To reduce microbial growth, packaging has to be combined with other treatments, such as refrigeration, which slow down or stop further growth of microorganisms. Meat can be packed in a variety of ways. Understanding the packaging options and their effects on meat is important, since they have an effect on its quality (Brody, 1997).

Currently there are many meat packaging systems, each with different attributes and applications. These systems range from overwrap packaging for retail display to a diversity of modified atmosphere packaging (MAP) systems and vacuum packaging for long-term display. The main reasons for MAP of red meats for retail sale are to prolong the microbiological shelf-life and maintain an attractive red colour of the product (Gill, 1996). The principle of MAP is to replace the normal atmosphere with a gas mixture that is suited to the food in question. The main gases that are used are nitrogen, carbon dioxide and oxygen. McMillin *et al.* (1999) define MAP as the removal or replacement of the atmosphere surrounding the product before sealing in vapour-barrier materials. The package protects products against deteriorative effects, which may include discoloration, off-flavour and off-odour development, nutrient loss, texture changes, pathogenicity, and other measurable factors (Yam *et al.*, 2005). One of the most important advantages of MAP is that it increases shelf-life, allowing less frequent loading of retail display shelves (Davies, 1995). Deterioration in appearance, bacterial spoilage, and loss of exudates are the main problems in the storage of chilled meat. Retail packaging of meat in MAP is used to provide a stable bloomed red meat colour, which is attractive to the consumer.

Vacuum packaging is used to prevent the growth of aerobic spoilage organisms, shrinkage, oxidation, and colour deterioration. McDonald & Sun (1999) highlighted that temperature and the microbiological status of the meat at the time of packing are most important. Overwrapping facilitates the oxygenation of the meat, causing the production of oxymyoglobin and the red 'fresh' meat that consumers tend to look for.

Fresh meat display

At display, the colour of meat plays a big role as it is always correlated with freshness and quality by the consumer (O'Grady *et al.*, 2000). Meat colour changes during display as myoglobin pigments on the meat surface transform on exposure to oxygen from primarily purple deoxymyoglobin to red oxymyoglobin and finally to brown metmyoglobin (Calnan *et al.*, 2014). The display point can be challenging to retailers as the meat might stay for a longer period. The display of meat in plastic materials allows consumer evaluation of the product in an attractive, hygienic and convenient package (Renerre & Labadie, 1993). Meat can also be displayed unwrapped in chilled display cabinets. Cabinets with humidity control reduce drying out. A shelf-life of one to two days is normal. Alternatively, meat is packaged for a variety of reasons. Over-wrapped packaging has a shelf-life of one to two days. Overwrapping trays with standard permeable film allows air to reach the meat to give a red colour and protects it from physical contamination. However, the meat soon oxidises, changing colour to dark brown. According to Liu *et al.* (1995), consumers discriminate negatively against meat that is discoloured. Meat with MAP has a shelf-life of seven to ten days (Bingol & Ergun, 2011). Meat is packed in trays with sealed lids that are impermeable to gases in air (usually transparent) and are thus packed with a high-oxygen modified atmosphere (Richardson *et al.*, 2009). This keeps the meat red for longer, but it turns brown eventually, usually with a rapid change from red to brown. Vacuum packaging gives meat a shelf-life of up to ten days (Peck *et al.*, 2006). Meat is maintained in the absence of air, so remains a purple-red colour. Prolonged pre-retail storage of meat is possible in vacuum packs, but only if the temperature is maintained at less than 3 °C.

At display, bacteria that affect meat, meat products and other food are divided into three groups according to the temperature range in which they can grow: mesophiles at 10–45 °C, psychrophiles at 0–28 °C and psychrotrophs at 10–45 °C, or slow growth at 0–10 °C. Mesophiles will not grow below 10 °C, but psychrotrophs, of which *Pseudomonas* are the more important, grow even at 0 °C. The nearer to 0 °C the storage temperature, the slower the growth of the spoilage bacteria and the longer the shelf-life (FAO, 1991).

Major challenges during distribution of meat

Microbiological meat spoilage

Meat is a good medium for bacterial growth, as shown by the numerous reports dealing with the influence of micro-organisms on the storage life of meat products. The main property that explains rapid microbial growth on meats is its composition: 75% water and many metabolites such as amino-acids, peptides, nucleotides, and sugars (Lawrie, 1985). Microbiological organisms and biochemical reactions are the cause of spoilage of perishable food, particularly where fresh red meat is concerned. Spoilage begins right after slaughter and is hard to prevent because the responsible organisms are already present in the food. In live animals, the internal organs are virtually sterile. However, other parts of the animal, such as skin,

hooves, and intestines, contain enormous numbers of bacteria (FAO, 2010). Depending on the slaughter hygiene, these bacteria find their way onto the carcass or contaminate the meat during slaughterhouse operations. Skinning, scalding, evisceration, dressing and carcass transport are common contamination points. Most bacteria are transferred to the carcass via butchers' hands, tools, contact with equipment and through water, air, etc. The bacterial contamination of meat is not stopped after slaughtering. It is on-going during the operations that follow the slaughter process, such as meat cutting and meat processing.

It is possible to reduce or decelerate bacterial activities. A well-known and proved measure is exposing them to cold temperatures. The characteristic microbial population that develop in meat and meat products depends on the effect of environmental conditions on the growth of those microorganisms, which are introduced because of contamination during handling and processing. Under some conditions, microbial growth may stop and then re-start after the microorganisms adapt to a new set of environmental conditions. Great economic losses have occurred from spoilage.

Meat spoilage is not always evident. Consumers would agree that gross discolouration, strong off-odours, and the development of slime constitute the main qualitative criteria for meat rejection (Nychas *et al.*, 2008). McDonald & Sun (1999) stated that meat is a highly perishable food product which, unless correctly stored, processed, packaged and distributed, spoils quickly and becomes hazardous owing to microbial growth. Meat is considered spoiled when it is unfit for human consumption (Bradeeba & Sivakumaar, 2013). Temperature and pH are among the factors that can affect the microbial spoilage of meat (Koutsoumanis *et al.*, 2006). The pH of individual meat influences the growth of spoilage bacteria, which should be taken into account when estimating shelf-life (Lawrie, 2006).

Foodborne pathogens in fresh meat

Food safety is a top priority for food service organizations because mishandling can result in serious illness for consumers, and business-related losses. According to some reports, the South African meat industry is facing the challenge of growth of foodborne pathogens that affect human health (DoH *et al.*, 2013). According to Cassin *et al.* (1998), there has been growing public concern over microbiological procedures that might mitigate the risk in food safety. Governments and industry have begun to focus attention on the production of foodstuffs as a source of risk to public health. In recent years, the occurrence of pathogenic micro-organisms in meat that affect human health has been noticed. Foegeding *et al.* (1994) stated that the cost of foodborne disease is estimated to exceed \$5 billion per year in the USA and \$1.3 billion annually in Canada (Todd, 2001). However, Smith *et al.* (2007) have highlighted that outbreaks of foodborne disease in humans are common in South Africa, but rarely reported. Sofos (2007) identified contamination from pathogenic microorganisms as the most serious meat safety issue, as it causes immediate consumer health problems and results in large-scale product recalls from the marketplace.

The consumer is the 'fork' in the farm-to-fork continuum, and harmful food pathogens can enter the food chain at any stage (Sargeant *et al.*, 2007). Most outbreaks of foodborne illness result from the transfer of harmful microorganisms from meat to humans. There are numerous diseases that humans may contract from endogenously infected meat, such as anthrax, bovine tuberculosis, brucellosis, salmonellosis, listeriosis, trichinosis, and taeniasis. Thousands of types of bacteria are naturally present in our environment and not all of them cause disease in humans. Bacteria that cause disease are called 'pathogens.' When pathogens enter the food supply chain, they can cause foodborne illness. Foodborne illnesses often present as flu-like symptoms, such as nausea, vomiting, diarrhoea and fever, and may lead to more serious complications. Each year, an estimated 48 million people in the USA experience foodborne illnesses and these cause about 3,000 deaths there annually (Scallan, 2011).

There are prominent pathogens that are associated with meat and meat products. *Campylobacter jejuni* is found in the intestinal tracts of animals. It causes foodborne illness and the characteristic signs are fever, headache, muscle pain, diarrhoea (sometimes bloody), abdominal pain, and nausea. These signs appear two to five days after eating food contaminated with this pathogen and the illness may last from seven to ten days

Clostridium botulinum is widely distributed in nature, for example in soil, in water, on plants, and in the intestinal tracts of animals. It grows in little or no oxygen. It produces one or more of seven toxins (A to G). Toxins A, B and E have been associated with human disease. Types A and B are more commonly linked with meat (Gracey *et al.*, 1999). This pathogen produces powerful neurotoxins that affect the nervous system. The symptoms usually appear within 18 to 36 hours, but may take as long as eight days. The symptoms include double vision, droopy eyelids, trouble in speaking and swallowing, and difficulty in breathing.

Clostridium perfringens is found in soil, dust, sewage, and the intestinal tracts of animals and humans. It grows in little or no oxygen. Symptoms of food poisoning from this pathogen in humans include diarrhoea and gas pains. These symptoms may appear 8 to 24 hours after eating, and usually last about one day, but

less severe symptoms may persist for one to two weeks. Human consumption of food contaminated with *Escherichia coli* O157:H7 produces symptoms characterised by diarrhoea or bloody diarrhoea, abdominal cramps, nausea, and malaise. The symptoms begin two to five days after food is eaten, and last about eight days. Some, especially the very young, may develop thrombotic thrombocytopenic purpura and haemolytic uremic syndrome, which causes acute kidney failure. *Escherichia coli* O157:H7 has emerged as a primary food safety concern in most countries. Mark & Roberts (1993) reported that the annual cost of *E. coli* O157:H7-related illnesses, estimated at 10 000–20 000, is between US\$216 and US\$580 million.

Listeria monocytogenes is found in the intestinal tracts of humans and animals, soil, and processed foods. The pathogen can grow slowly under refrigeration. Most human cases are sporadic and the illness is systemic. The symptoms are fever, chills, headache, backache, sometimes abdominal pain.

Staphylococcus aureus is usually transmitted by people to food through improper handling. The pathogen multiplies rapidly at room temperature to produce a toxin that causes illness. Symptoms in humans are severe nausea, abdominal cramps, vomiting, and diarrhoea. These symptoms may occur one to six hours after eating contaminated food.

Salmonella spp are found in the intestinal tract and faeces of animals. Infections in humans occur through consumption of poorly cooked meat or raw meat. The symptoms are stomach pain, diarrhoea, nausea, chills, fever, and headache. These symptoms usually appear six to 48 hours after eating and may last one to two days.

Decontamination procedures with water sprays (potable water or hot water with temperature below 75 °C operated under high pressure), physical methods (use of ultraviolet light, ionizing radiation and ultrasound) and chemical techniques (use of chlorine, hydrogen peroxide, trisodium phosphate and organic acids) have been employed in South African abattoirs, to reduce initial microbial load on carcasses and prolong the shelf-life of meats (Warriss, 2000). However, further research on microbial growth on carcasses at each stage of distribution is encouraged.

South African meat safety law – How and where is it violated?

In any food supply chain, regulations are set by government, which must be followed. The South African Meat Safety Act governs the regulation of meat and meat product distribution. Its mandate is to ensure that the food safety requirements set by the government are met. The role of the act is to provide for measures to promote the safety of meat and animal products; to establish and maintain essential national standards for abattoirs; to regulate the importation and exportation of meat; and to establish meat safety schemes. One of the most important measures to promote meat safety in this act states that the slaughtering of animals in any place other than an abattoir is prohibited, and that no meat or animal product may be sold if it was not obtained from an abattoir. These rules are set to ensure that any meat provided or sold to the public is hygienically approved and is safe for consumption. Approved abattoirs operate on the basis of a valid registration certificate as proof that they have met certain requirements relating to structure and layout. Such abattoirs are required to have qualified meat inspectors and meat classifiers, and are inspected regularly to ensure they meet hygiene requirements for the removal of sick, infected and contaminated meat and animal products from the food chain.

However, some sectors in the meat supply chain violate this act by not adhering to the legal requirements, standards and procedures set by government. These are the informal meat marketers. In the informal sector, standard and hygienic methods of handling and processing meats are given less attention even though they form part of the country's rules and regulations on animal and meat production. The South African Red Meat Marketing Association has indicated that in the informal food chain, meat is mostly supplied by communal farmers (Van Zyl *et al.*, 2006). The main disadvantage of the informal sector is that the meat is not inspected and lack of meat inspection results in contamination, which causes foodborne illnesses. A comparison between the formal and informal meat supply and distribution chains is given in Table 1.

Foodborne illnesses have been reported to account for the majority of illnesses in most developed countries. According to World Health Organization (WHO, 2010), 1,8 million deaths from diarrhoeal diseases were caused by contaminated food. It has also been reported that 30% of populations in industrialized countries succumb to foodborne illnesses every year. According to Frean *et al.* (2003), foodborne disease is a common public health problem worldwide, but is generally under-reported and poorly investigated in South Africa and southern Africa.

Table 1. Comparison of the slaughter and meat processing chains in the formal and informal meat trades in South Africa.

Slaughter/Meat Processing	Formal Meat Trade	Informal Meat Trade	References
Before slaughter	Animals are inspected before slaughter Animals are rested and walk in pens Feed is withdrawn 12–24 h before slaughter to reduce the risk of contaminating the carcass with the gut content during evisceration	No inspection before slaughter Animal is chased, exhausted and fights with the people before slaughter Animals are fed till slaughter	Adzitey <i>et al.</i> (2011), Grandin (2000), Seeiso (2009)
Slaughter condition	Hygienic conditions	Unhygienic conditions	Niyonzima <i>et al.</i> (2013)
Animal welfare ethics	Follow them	Do not follow them	Grandin (2000)
Stunning methods	Stunning methods applied	No stunning methods applied	Njisane & Muchenje (2013)
Skinning	Sophisticated skinning machine	Unsterilized knives and feast	Seeiso (2009)
Bleeding	Horizontal and proper bleeding	Vertical bleeding. lying on the ground, no hanging	Njisane & Muchenje (2013)
Carcass exposure	Hanged	Carcasses left lying on the ground or placed on top of the skin	Adzitey & Huda, (2011)
Chilling	Carcasses are chilled	No chilling	Adzitey & Huda, (2012)
Protective clothing by meat handlers	Wear protective clothing	Do not wear suitable protective clothing	Njisane & Muchenje (2013)
Skills and training	Training on meat handling	No training	Adzitey <i>et al.</i> (2011a)
Carcass inspection	Carcass is inspected	No inspection	Soji <i>et al.</i> (2014)
Carcass grading	Carcass is graded	No grading	Strydom, 2011
Transportation	Carcasses transported by trucks with controlled temperatures	Vehicles used often dirty; meat stored on the floor of the vehicle	Vimiso & Muchenje (2013)
Cutting	Use cutting machine	Split on ground	White (2006)
Display	Accumulation of air minimised and packaging is used	Meat is exposed to air, risk of cross-contamination -Products are open to contamination Meat is not refrigerated	Renner & Labadie (1993), Soji <i>et al.</i> (2014)
Cold chain	Temperature is controlled	No temperature control	Richardson <i>et al.</i> (2009)
Market	Reliable	Not reliable	Soji <i>et al.</i> (2014)

Informal meat trade vs the Meat Safety Act No. 40 2000

Small-scale farmers–Backyard slaughtering

In the majority of cases, the informal sector in South Africa does not adhere to the legal requirements, standards and procedures that the formal sector follows before and after slaughter. Before slaughter, the animal is usually chased by a number of people, and by the time of slaughter, it is exhausted. Stunning methods are generally not applied, and this compromises the animal's welfare. The way in which animals are handled on the slaughter floor can affect the quality of the product (RMAA, 2011). Carcass and meat quality defects such as pale soft exudative meat, dark firm and dry meat, skin blemishes, blood splashes, bruising, cyanosis, two-toning, high microbial load, spoilage of meat, broken bones and death may occur from improper animal handling (Adzitey *et al.*, 2011a; Warriss, 2000).

In the informal sector, there are inappropriate slaughtering facilities and techniques that can compromise food safety. Informal slaughtering places are frequently unhygienic and meat is easily contaminated (Niyonzima *et al.*, 2013). Meat products from such conditions often deteriorate rapidly.

According to the Meat Safety Act (2000), surface contamination of carcasses during slaughter and processing can be reduced by ensuring good practices such as hygiene and sanitation of the floor, equipment, and carcasses with suitable disinfectants and sanitizers. However, disinfectants and sanitizers are seldom used in the informal sector. Slaughtering places are frequently contaminated, and may not be protected against dogs, rodents, and insects, and thus the level of bacterial contamination is increased. In some rural areas, perhaps owing to constraints such as inadequate education, unavailability of potable water and unreliable power supply, meat processing is traditionally carried out in unhygienic conditions. Slaughter methods are sometimes dictated by religious beliefs and local customs without inspection by a qualified veterinary officer. However, this is an unfortunate situation because this meat is sold to consumers in the communities. Consumers tend to assume that the meat is safe, no matter where it is purchased (Grunert, 2005).

In the formal sector, immediately after slaughter, carcasses are chilled and are usually kept under refrigerated conditions to control the growth of spoilage organisms (Adzitey & Huda, 2012). Since the small-scale producers do not necessarily follow the Meat Safety Act 2000 regulations, slaughtering is often done unhygienically, resulting in high numbers of organisms on the carcass. There is also improper and insufficient bleeding of the animals, leaving a relatively high amount of blood in the muscle (Seeiso, 2009). Blood is a good medium for bacterial growth. There is improper de-hiding of the carcass, leading to heavy contamination of the meat surfaces by frequent contact with the people slaughtering the animal, the polluted environment, dirty tools and equipment, contamination of the meat when carcasses are split on the ground, and lack of refrigeration. All these factors, together with the high pH of the meat, which is a result of the animal being stressed before slaughter, lead to heavy contamination of the carcasses by organisms, which lead to a short shelf-life.

Street vendors

Street meat vending is thought to supply a significant income for households involved in selling the meat. However, there is a general perception that street-vended foods are unsafe, mainly because of the environment in which they are prepared and consumed, which exposes the food to numerous potential contaminants (Adzitey *et al.*, 2011). Street meat vendors usually take their products to their customers, and therefore operate from places such as bus terminals, industrial sites, marketplaces, and other street corners. Unfortunately, these locations seldom meet all food safety requirements. The Foodstuffs Cosmetics and Disinfectants Act (Act No. 54 of 1972) prevents any person from selling food that is unfit for human consumption (DoH, 2012). In addition, the Codex Alimentarius or code of ethics for international trade in food states that all consumers are entitled to safe, sound and wholesome food and must be protected from unfair trade practices. Thus, by implication, this code of ethics prohibits any person from putting any food that is unfit for human consumption into international trade.

In street vending, the meat is usually displayed with or without packaging (Adesiyun, 1995). Meat is a perishable food, and can be harmful to health if improperly handled, especially products containing blood, which creates favourable conditions for bacterial growth. Contamination can take place through flies, dust, moulds, poor hygiene, especially by street vendors who do not wear gloves or protective clothing, and lack running water to wash utensils. All compromise the microbiological quality of meat drastically, and thus these factors pose a serious health threat to the public.

Meat is a high-risk food and should not be out of cold storage for more than four hours. According to Sofos (1994), microorganisms multiply rapidly in fresh meat and unprocessed products, especially at non-refrigeration temperatures, resulting in loss of quality and public health problems. However, for street vendors, the meat could be displayed for more than six hours. Temperatures for keeping this meat are uncontrolled or depend on the environmental daily temperatures. Meat is sensitive to temperature changes and must be stored at 5 °C to 10 °C from abattoir to consumer to minimize the growth of bacteria (Carvalho, 2012).

Another food safety concern is when meat is not purchased on a specific day. Usually street vendors store this meat overnight in refrigerators, merely to be taken back next day to sell. With this, the breakdown of lipids may occur and some of the valuable technological attributes of meat such as colour and tenderness are already compromised, but most importantly the safety of the consumer is not taken into consideration. The breakdown of lipids may result in colour changes, rancidity, and tallowy or chalky flavours (Faustman & Cassen, 1990). Colour changes as a result of pigment oxidation may show grey, brown, or green discoloration.

Bacteria develop in meat exposed by the vendors during the day owing to thawing because the meat is not refrigerated. This is compounded by other environmental factors such as flies, dust, and moulds. If this meat is not purchased, vendors tend to take it back to the refrigerators and re-sell next day. When re-selling, it means that the number of bacteria growing in that meat will multiply. Vendors do not use gloves when

handling the meat, hence cross-contamination takes place. Regulations concerning hygiene when handling meat have already been violated. Zahid *et al.* (2002) reported that the amount of bacterial growth in meat that is thawed or stored in the refrigerator is less than bacterial growth in meat thawed or stored at room temperature. By displaying the meat on the street, it is exposed to aerobic spoilage by bacteria and yeasts, which may result in slime formation, undesirable odours and flavours (taints). Aerobic spoilage by moulds results in a sticky surface, musty odours, alcoholic flavours and creamy, black and green discoloration. Proper cooking and processing of food destroy bacteria. After purchase, whether contaminated meat is washed and cooked at temperatures that would inhibit or kill the bacteria, consumer health is still exposed to high risk.

Therefore measures must be taken to educate street vendors that sell meat. Hence revisiting the regulations in the act that were set by government to accommodate meat street vendors might help. This might assist in alerting street vendors to meat safety measures and minimize the risk of exposing consumers to these conditions. Promoting better meat handling in the informal sector would result in fewer economic losses and more meat products would be available to the consumer via retailers. More and safer meat products would mean an opportunity for small-scale producers to join the supply chain legally and their products would be marketed in local and export markets, thus earning more foreign currency. In this manner small-scale producers and consumers would all benefit.

Conclusion

The meat distribution chain is an important aspect in the meat industry and the cold chain affects the safety and quality of meat. During distribution, pathogenic and spoilage micro-organisms may grow. Therefore, storage temperatures must be maintained to control microbial growth. Food safety should be a top priority for food service organizations because mishandling may result in serious illness for consumers. Meat that is not properly stored and handled during distribution may not be safe for consumption. The types of meat, methods of packaging, and storage conditions affect the storage life and the microbiological status of the meat product. Maintaining temperatures during distribution is the major key to keeping the quality of meat. Changes in meat quality and bacterial growth in each stage of the distribution chain must be determined. Moreover, a food safety knowledge gap in the informal sector has been identified. Therefore, better efforts to provide high-quality meat and meat that is safer, especially in the informal sector, should be considered. South Africa is in a developmental state and therefore government has a role to develop and intervene, and try to incorporate informal meat traders in order to produce meat that is safer for consumption and align their sector with the regulations governing food production. Government is expected to assist in providing meat inspection services for the informal meat industry to ensure fair trade and enable informal meat marketers to slaughter their livestock close to where the animals are raised. Governments have the responsibility of ensuring that all consumers have access to safe meat.

Acknowledgements

The authors would like to thank the Red Meat Research and Development of South Africa (RMRD-SA) and the SA National Research Foundation /Research and Technology Fund (NRF/TRF) (Grant RTF 14013062856) for supporting this research financially.

Authors' Contributions

ZTR conceptualised and drafted the review article. AH, CJH, PV and VM were responsible for the development, editing and submission of the article.

Conflict of Interest Declaration

There are no conflicts of interest.

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