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A review on microbial hazards associated with meat processing in butcheries

--Manuscript Draft--

Full Title:	A review on microbial hazards associated with meat processing in butcheries
Manuscript Number:	RAJS-2015-0117R1
Article Type:	Original Article
Keywords:	Equipment; food handlers; foodborne illness; meat hygiene; pathogenic bacterial and possible contamination.
Abstract:	Meat is known to be highly nutritional and rich in proteins, which makes it a good substrate for possible microbial growth. As a result, meat in its raw state is easily susceptible to colonization by microbes. This study briefly describes the possible sources of contamination linked with meat handlers within butcheries and also microorganisms that able to contaminate meat and cause a possible variety of illness. It also reflects on knowledge and behaviour of the food handlers, equipment and working surfaces as critical potential sources of contamination. Meat processing hygiene is part of Quality Management (QM) of abattoirs and butcheries and refers to the hygienic measures to be taken during the various processing stages in the processing of meat products. In conclusion, as contamination of meat may exist from food handlers, the production chain and equipment used, it is fundamental to identify possible contamination sources and types of microbes associated with such contamination. The latter is important for optimising hygiene practices in butcheries and minimising possible health related risks.
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Response to Reviewers:	LETTER TO THE REVIEWER Date: To: AJSTID Ref: Ms. No. RAJS-2015-0117 E-mail: shalek@tut.ac.za and takalanimatodzi7@gmail.com Re: Submission of the amended and edited manuscript (AJFS RAJS 2015-0117) Included please find a copy of amended manuscript “AJFS RAJS 2015-0117” with a rephrased title to “A Review on Microbial Hazards Associated with Meat Processing in Butcheries” submitted to your journal for publication. We found the comments of the reviewer helpful and made adjustments accordingly. Enclosed are the following files: manuscript and tables both in Microsoft Word format and comments addressed in the pages below the cover letter. On the other hand, we kindly request that all correspondences be addressed to Prof Karabo Shale as I will be changing my position and don’t want to lose track of the publication. His email is shalek@tut.ac.za as also reflected above. May you please send also to my private email: takalanimatodzi7@gmail.com Moreover, we added two authors who were also working with us. Our reason to remove them initially was due to the comments made on one of the papers we once submitted about the number of authors (Name of the authors: F. Machete and C. Tshelane).

We trust that you will find it in order.

Best regards
Mr. Matodzi Takalani

Comments to the reviewer

Journal requirements of the journal
The following were noted and amended accordingly:

Page 1:Title has been changed.
Page 2:The abstract has been changed into a journal structure, e.g., table has been removed.
All pages: the format both text and references has been changed into journal style.

General changes:
The following were noted and amended accordingly:
All pages:Spacing has been inserted in all sentences' were it was not inserted

Analytical framework reviewer 1: Analytical data was there to support what has been done by other authors in order to highlight the need for a database in South Africa to capture all outbreaks of food poisoning.

Spelling: typing error and also wrong spelling has been changed in all paragraphs.

Grammatical corrections:

Page 2:
Abstract: changes have been done and replacement of words, for examples:
Line 1, "and" has been replaced by the word "which" and also line 2, the sentence has been rephrased from "The present review paper" into "This study", same with the word "covers" to "describes".
Line 4-5, the word "are" has been added between "that able" and also the words "The paper" has been replace with an appropriate word "it".
Line 6, the word "and" has been added after the word "equipment" and also in line number 9, the word "steps" has been replaced with "stages" in the paragraph.
Line 10, "The" was added before the word "production", this ";" was replaced with a comma "," after the word "used".
Line 11, the words "as such it is also important for hygiene practices in butchery" was removed after the word "contamination".
Line 12, the "in" was replaced with "for optimising hygiene practices in butcheries and" between the words "important" and "minimising".
In line 13 after the word "risks", the word "within butcheries" was deleted.

Under Introduction:
Line 5, "," was replaced with the word "and", also line 8 a "comma" was added after the word "countries".

Under Raw Meat:
Line 1, after "literature", the word "indicates" has been added to replaced "shows"
Line 6, the word "microorganism's" was changed into plural "microorganisms'".

Under Food Handlers and Hygiene Practices:
Line 2, a "comma" was added after the word "cuts".
Line 3, after the word "meat", "getting" was replaced by "becoming"
Line 4, ";" was replaced with "and". Also in line 7, spacing was inserted between "surfaces.Several"

	Second paragraph: Line 1, “the” was added before “farm-to-fork” and also in line 5, the word “of” was deleted between “most animals”. Second paragraph: Line 3 “,” was added after the word “contamination”. Under Transportation: Line 3, spacing has been inserted between “1972”, and also in line 6 “transport” has been changed to “transportation”. Second paragraph: Line 2, “direct” was added between “into contact” and the word “anyway” was changed to “any way”, line 3. Line 6, “,” was inserted after the word “Therefore” and “temperature” was changed into “temperatures” (line 7). Under Bioaerosols: Second paragraph: Line 7, the word “meaning” was changed into “importance” between “vital to” and also in line 9, after “necessary”, the word “stop” was changed into “prohibit”. Under Biofilms: Second paragraph: Line 7, “The” was added after the word “Therefore,” and also in line 8, after the word “major”, “problem in the” was replaced by “concern for”. Under ATP (Adenosine Tri-Phosphate) Hygiena: Line 7, between “surface including”, a “comma” was added Second paragraph: Line 5, after the word “assessments”, “,” was replaced with “and”, also “,” was added after the word “methods”. Line 6, “evaluating the” was added after the word “when” and also in line 7, a “comma” was added after the word “areas”. Under Public Health Disease Surveillance System: Second paragraph: Line 3, the following words has been changed from-to “collecting-collect, managing-manage, analysing-analyse, interpreting-interpret and disseminating-disseminate” Line 4, after the word “furthermore,” “it” was inserted and the word “provide” was changed to “provides”. Line 5, after the word “disease”, the word “trend” has been changed to “trends”. Third paragraph: Line 2, “state-health”, was changed in to “state health”. Under Pathogenic Microbes: Line 1, “whetherin”, was changed to “whether in”, also the word “they” has been removed before the word “both”. Line 3, a space has been inserted between “coli0157:H7” to be “coli 0157:H7”. Third paragraph: Line 3, the word “a” has been added before “CDC”, “which” has been replaced by “to”, after the word “system” and also the word “records” has been changed to “record”. Under The role of the municipality (and EHPs) regarding the butchery: Line 1, “A” has been added before the word “butchery”. Under The role of the National Department of Health: Line 2, after the word “level,” “the” has been added, after a word “directorate”, a “comma” has been deleted. Line 3, a comma has been added after the word “Directorate” Line …., …….. Line 8, “EHP’s” has been change to “EHPs” and also a sentence “The role of the municipality (and EHPs) regarding the butchery” has been shifted down as it was a new sub-topic. Second paragraph: Line 1, the word “acceptance” has been changed to “acceptability”.

	Line 3, between “is carried”, the word “often” has been deleted and also “EHP’s” has been change to “EHPs”. Third paragraph: As the reviewer said that EHPs are trained, yes they are but only at first level and this doesn’t make them to be well qualified for microbiological analyses so I then rephrase the sentence to “Although South African EHPs are trained in microbiological analysis of food at first year level, this does not make them competent enough towards proper understanding and interpretation of data they received from microbiologist. Additionally, in some instances, EHP’s end up using visual inspections instead of evidence based data because very few local authorities have laboratories. The use of on-site quick and/or instant analysis instruments for detecting possible contaminants in food is currently not in existence”. Under conclusion: Line 5, between “and meat”, “the” has been added. Line 8, after the word “should”, the word “posses” has been replaced with the word “be guided by” and the word “food safety system, indicating the” has been added before the word “schematic”. References: All references have been changed into AJSTID style, for example: 1. Ali NH, Farooqui A, Khan A, Khan YK and Kazmi SH. 2010. Microbial contamination of raw meat and its environment in retail shops in Karachi, Pakistan. Journal of Infection in Developing Countries, 4(6), 382–388. Journal style: Ali, N. H., A. Farooqui, A. Khan, Y. K. Khan, and S. H. Kazmi. 2010. Microbial contamination of raw meat and its environment in retail shops in Karachi, Pakistan. Journal of Infection in Developing Countries 4(6): 382–388. Reference has been added as it was only in table 1 but not in the reference list: Ak, N. O., D. O. Cliver, and C. W. Kaspari. 1994. Cutting boards of plastic and wood contaminated experimentally with bacteria. Journal of Food Protection 57(1): 16-22. Page 11, between “ref. South Africa, Department of Health. 2003.” And “South Africa, Department of Health. 2012.” this reference “South Africa, Department of Health. 2003. Health Act (Act no. 63 of 1977). Government gazette no. 26595. Pretoria: Government Printer.” has been deleted due to the change in the paper and also in table 2. Table 2 (page 14): a column of Health Act 61 of 2003 has been deleted as the information that was on it is now falls under “Act 54 of 1972 (Foodstuff, Cosmetics and Disinfectants Act)”.

A review on microbial hazards associated with meat processing in butcheries

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Abstract

Meat is highly nutritional and rich in proteins, which makes it a good substrate for possible microbial growth. As a result, in its raw state meat is easily susceptible to colonisation by microorganisms. This study describes the possible sources of contamination associated with food handlers within butcheries and also microorganisms that are able to contaminate meat and cause a possible variety of illness. It also reflects on knowledge and behaviour of the food handlers, equipment and working surfaces as potential sources of contamination. Meat processing hygiene is part of Quality Management (QM) in abattoirs and butcheries. The QM refers to the hygienic measures taken during various processing stages of meat products. Hence, contamination of meat often caused by food handlers, the production chain and equipment used. Therefore, it was fundamental in this study to identify possible contamination sources and types of microorganisms associated with such meat safety contamination. The latter is important for optimising hygiene practices in butcheries and minimising possible health related risks.

Keywords: equipment, food handlers, foodborne illness, meat hygiene, pathogenic bacterial and possible contamination.

Introduction

Meat safety is a major priority of most meat producers, processors and consumers. This is due to a number of publicised food scares and outbreaks worldwide such as Bovine Spongiform Encephalopathy (BSE), avian flu, foot and mouth diseases, some emerging and/or evolving pathogenic bacteria such as *Escherichia coli* 0157:H7 and *Listeria monocytogenes* (Sofos 2008; Seeiso 2009). Despite the number of meat exports and food safety education offered to meat business operators and processors in South Africa, foodborne illnesses from the consumption of contaminated meat remain a public health concern in developed and developing countries, including South Africa (Griffith 2006; Jacob et al. 2010). In general, meat contamination is associated with inappropriate farming practices. Thus, it is crucial to improve the "farm-to-fork" practices in order to prevent, reduce and/or at least control a number of foodborne diseases related to meat production (Jacob et al. 2010).

In addition to the "farm-to-fork" method, it is important to monitor all aspects of animal husbandry of each farm as part of meat hygiene practices. The monitoring should be aimed at producing safe and healthy livestock. This is significant, given that farm animals are the original source of many foodborne pathogens that cause diseases in humans. However, most animals are asymptomatic; they show no symptoms of illness although their dung and other body fluids remain pathogenically infectious (Ateba et al. 2008; Behravesh et al. 2012). To avoid and control cross contamination, farmers, veterinary and other meat safety related practitioners need to ensure that only healthy animals that are suitable for loading, transportation and slaughter for meat purposes are loaded, transported and processed in abattoirs (Nørrung & Buncic 2008). Therefore, it is important that high levels of hygiene are maintained in any business that handles or processes food and meat for human consumption.

Possible sources of contamination

Raw meat

Literature indicates that the muscle tissue of a healthy living animal is free of microorganisms and the under skin of animal carcass becomes sterile immediately after slaughter (McEvoy et al. 2000). Hence, contamination of raw meat may be due to slaughtering of stressed animals, as well as contact with external surfaces such as hair, gastrointestinal and respiratory tracts and/or other ambient environmental hazards. In the abattoir, contamination occurs with the microorganisms' introduction to direct meat contact with surfaces in operations performed during offloading, weighing, processing, cutting and storage, as well as at the points of sale and distribution (Nørrung and Buncic 2008; Sofos 2008; Ali et al. 2010). Bas et al. (2006) further stated that pathogens are passively transmitted from a contaminated source such as raw poultry to cooked food that is prepared for later consumption as cold foods. Typical microorganisms that are usually prevalent in raw meat include *Listeria monocytogenes*, *Salmonella*, *Staphylococcus aureus*, *Campylobacter* (on poultry), *Escherichia coli* and *Escherichia coli* 0157:H7 amongst others (Ateba et al. 2008).

Food handlers and related hygiene practices

Meat cutting is important in meat processing as carcasses are deboned and cut into smaller and more desirable cuts, using hand tools and machines (Wang and Shanmugam 2009). Hence, the risk of meat becoming contaminated depends largely on the health status of the food handlers, their personal hygiene and knowledge and practice of food hygiene (Collins 2001). According to Nørrung and Buncic (2008), the process of meat handling increases the possibility of microbial contamination because unhygienic practices during handling may lead to transmission of bacteria to the meat from the surfaces. Several studies have further indicated that foodborne illnesses occur due to poor handling of food (Van Tonder 2004; Griffith 2006). *Staphylococcus*-related food poisoning has been linked to food handlers who are known to be carriers of this bacterium (in their skin, infected cuts, nose, throat, etc.) in meat establishments (Van Tonder 2004). In addition, Kusumaningrum et al. (2002) further indicated that various bacteria, amongst others *Staphylococcus aureus, Escherichia coli* and *Salmonella* spp., survive on hands and surfaces for hours or even days after initial contact with the microorganisms.

In addition, 97% of food consumers' illnesses in the USA were linked with improper food handlers' practice in the food-service industry (Bas et al. 2000). Food handlers may on some occasions serve as sources of contamination, especially as a result of some having gastrointestinal illnesses or convalescence process when symptoms have disappeared.

Transportation

Good quality meat with an adequate shelf life can be ensured by the proper maintenance of the cold chain. Hence, South African Regulation 962 of 23 November 2012 framed under the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act no. 54 of 1972) and the Meat Safety Act 2000 (Act no. 40 of 2000) (table 2) clearly reflects and stipulates that all food specified under the regulation and act must be kept at a low temperature or below (4ºC) during storage, transportation and while on display.

In addition, no food may be transported simultaneously with any person or items, or in such a manner that it comes into direct contact with the floor or anything else that can pollute, spoil or contaminate the meat in any way (Van der Walt 2005). Thus, inspection of incoming meat and temperature checks of both the meat and transport used are of principal significance as described in the South African Regulation 962 of 23 November 2012 under the Department of Health (DOH). Therefore, proper transportation of carcasses and meat products together with the maintenance of refrigeration temperatures will reduce the potential for contamination.

Bioaerosols

The microbial contamination of meat and meat products in the past was thought to occur only due to direct contact with contaminated surfaces. However, airborne microorganisms, dust, pollen and mould spores which may be present in ambient air, are contaminants that easily find their way into meat products (Sutton 2004). These airborne contaminants are also known as bioaerosols, and may include bacteria, fungi, viruses, pollen, toxins and other contaminants of non-biological and biological origin (Shale et al. 2004; Nkhebenyane 2010).

Several studies have indicated a range of routes through which microorganisms can be distributed through ambient air during talking, sneezing, coughing and high pressure spraying (Cundith et al. 2002; Shale et al. 2004; Sutton 2004). Furthermore, wastewater, sink and floor

drains, including spilled products that become aerosolised, can also be major sources of bioaerosols causing harm to both the consumer and butchery worker's health. This may possibly lead to the reduction of meat quality, its shelf life and that of other meat products. Therefore, the use of air filtration is of vital importance to ensure fine quality of air in high risk areas such as the preparation and packaging areas, as well as at the purchasing point (Patel 2009). However, such methods do not necessarily prohibit the distribution of bioaerosols in food processing areas.

Biofilms

Biofilms are microbial populations (mainly bacteria) that have the ability to adhere to different surfaces. They are also Extracellular Polymeric Substance (EPS) producers, which are highly hydrated with chemically complex matrix (Hall-Stoodley et al. 2004). The characteristics of EPS are indicated as a reason for the resistance of treated biofilms to sanitising, rather than intrinsic attributes of the cells in the biofilm (Pan et al. 2006).

Studies have illustrated that common sanitation practices are less effective in removing biofilms as compared to free cells (Meyer 2003). The leading causes of the nosocomial infections in the USA, among other countries, are biofilm-related infections sourced by staphylococci (Kong et al. 2006). Studies have also shown that, as in other food sectors, the meat industry is faced with increasing demands in terms of cleaning and disinfection in order to remove microbial coatings such as biofilm which may take days or hours to form (Stopforth at al. 2002). Therefore, the presence of biofilms in the food industry can be a major concern for public health.

Equipment and utensils

Hygienic design features equipment may still become contaminated by microorganisms, workers, bioaerosols and other materials during processing (Evans et al. 2004). Many foodborne disease outbreaks are associated with improperly cleaned utensils and equipment.

According to Gill and McGinnis (2000), meat residues that are not removed from meat contact surfaces during cleaning were indicated to be the primary source of *Escherichia coli* deposited on the meat. *Listeria monocytogenes* is an environmental bacterium which can harbour and thrive in meat processing equipment such as slicers, dicers and machinery for packaging, which are insufficiently cleaned and sanitised (Tompkin 2002; AMI 2008). Table 1 indicates most commonly used equipment and utensils in the butcheries and the prevailing micro-organisms.

[Table 1 here]

ATP (Adenosine Tri-Phosphate) hygiena

The formation of biofilms on equipment and/or utensils is a great concern in the meat industry. With the above in mind, it is then crucial to note that visual inspection is performed in food premises to check equipment used and working surfaces. Thus, it is crucial to use "ATP Hygiena" method to evaluate the cleanliness of working surfaces (Attala & Kassem 2011). Moore et al. (2010) further explained Adenosine Triphosphate (ATP) as an enzyme that is present in all living cells. This method also detects and reflects the amount of organic matter that remains after cleaning an environmental surface, including the equipment. The amount of ATP and where it was detected indicates areas and items in the healthcare setting

that may need to be re-cleaned, and a possible need for improvement in a healthcare facility's cleaning protocols (PIDAC 2012).

As stated before, the primary monitoring of any cleaning programme is visual cleanliness; it involves the assessment of a surface as being free from food debris and other soiling by a person without any sampling aids. This may involve looking at the surface, feeling the surface for any signs of hidden deposits such as grease, oils and even smelling the equipment. In Egypt, most local health departments utilise visual assessments and not microbiological methods, when evaluating the hygiene status of a butchery area in small scale processing plants (Attala and Kassem 2011). However, the use of ATP Hygiena is still lacking and not well documented in some areas, particularly in butcheries.

Public health disease surveillance system and related pathogens

Public health disease surveillance system

In South Africa, food poisoning became a notifiable medical condition in 1990; however, the condition is less likely to be reported due to lack of efficient and integrated foodborne surveillance systems (South Africa, Department of Health 2007). In comparison, internationally, CDC's (Centre for Disease Control) National Notifiable Diseases Surveillance System (NNDSS) utilises a multifaceted Public Health disease surveillance system that gives public health officials powerful capabilities to monitor the occurrence and spread of diseases.

This section of CDC is used by numerous states, territorial, tribal, and local health departments; and by partner organizations such as the Council of State and Territorial Epidemiologists (CSTE), to facilitate, collect, manage, analyse, interpret and disseminate health related data for diseases designated as nationally notifiable. Furthermore, it provides detailed data to CDC programs to aid in identifying specific disease trends, work with states and partners to implement and assess prevention and control programs, and publish summarized data findings weekly and annually in the Morbidity and Mortality Weekly Report (CDC 2014).

Unfortunately, South Africa lacks such a structure and there is a dire need as this system is an effective public health surveillance that must begin at the local- and state health department levels. Moreover, government must work with a variety of healthcare providers, including laboratories, hospitals and private providers, to obtain case reports on many infectious and some non-infectious diseases. Each province must have by laws mandating that providers report cases of certain diseases to province and/or local health departments (CDC 2014).

Pathogenic microorganisms of concern

Whether in raw or processed meat, both usually contain bacteria or other microorganisms. Most of them are harmless whilst some could be a threat to food safety as they are food poisoners. Therefore, principal pathogens of concern are *Staphylococcus aureus, Escherichia coli* 015:H7 (ruminants), *Salmonella* spp. (all meats), *Listeria monocytogenes* (all meats), *Campylobacter jejuni* (poultry) and *Yersinia enterocolitica* (pork) (Kusumaningrum et al. 2002). This microbiota has been associated with food-borne illness outbreaks and even death to many people each year (Borch and Arinder 2002). In addition, the largest outbreak of *E. coli* 0157:H7 occurred in South Wales in 2005 where a total of 157 cases were identified. A

hundred and eighteen of these cases were confirmed positive for *E. coli* 0157:H7 and 31 school children were admitted to the hospital. One death (of a 5-year-old) was reported after consumption of sliced cooked meat and other types of meat supplied by John Tudor and Sons, a catering butchery business (Pennington 2009; Powell et al. 2011).

On the other hand, *Listeria monocytogenes* was reported to have caused an outbreak of food poisoning after consumption of deli meats in Toronto butchery in 2008. The cause of this outbreak was mainly due to trapped meat residues in meat slicing machines which provided a reservoir for *L. monocytogenes* (Pennington 2009). A decade earlier than the latter (during 1999), it was estimated that foodborne pathogens caused 76 million episodes of illness, resulting in 325,000 hospitalisations and 5000 deaths in the United States alone (Osterholm 2011). The Centre for Disease Control and Prevention estimates that there have been approximately 48 million foodborne illnesses, 128,000 hospitalisations and 3000 deaths post 1999 until the 2011 (CDC 2011).

In South Africa as reported by Powell et al. (2011) and Halliday et al. (2012), it remains a challenge to enforce regulations in some sectors due to the lack of surveillance data which results from lack of outbreaks data. This is because of the absence of a CDC system to record the data of outbreaks of foodborne diseases between 1999 and 2010. However, as reported by Sofos (2008), the 1999 estimates cannot be compared with the current ones for purposes of trend analysis due to the fact that different diagnostic methods evolve all the time. Furthermore, the epidemiological data of foodborne illness and surveillance estimated by the U.S. (CDC 2011) such as Food Net and the pathogenic tracking and DNA fingerprinting program (PlusNet) indicated that approximately 60-70% of outbreaks and 40-50% of foodborne illness cases reported remains unresolved as well as the etiologic agent unknown.

Legislation and governance concerned with South African butcheries

Food safety, hygiene legislation

There are laws and regulations in place to secure hygienic conditions and practices to protect the consumers against potential risks of food poisoning (Table 2).

[Table 2 here]

The role of the National Department of Health

The Department of Health's responsibility is to make a contribution to protect South African people from harmful effects of unsafe foods. At a national level, the food control directorate, incorporated in the Chief Directorate, is directly responsible for all matters related to food safety control. In addition, regulation (R.908 of 2003) makes it mandatory for listed food processing institutions to implement HACCP in order to promote food safety and protect public health (South Africa, Department of Health 2003). Although the implementation of HACCP is not mandatory to butcheries, as they are not part of the listed food processing institutions, voluntary adoption of HACCP in all butcheries is encouraged in order to prevent, reduce and/or control meat safety or related hazards and improve the quality of meat and other meat products.

The role of municipality (and EHPs) regarding the butchery

A butchery, by virtue of being a food premises, is required by law to observe all regulations governing food safety and hygienic premises as contained in the Foodstuffs, Cosmetics, Disinfectants Act, 1972 (Act no. 54 of 1972), according to which butcheries are classified as "food premises". Also, "food premises" must comply with the regulations as set out in the Government Notice as R.962 "Regulations Governing General Hygiene Requirements for Food Premises and the Transport of Food".

Once in compliance, butcheries are expected to display valid certificates of acceptability (The Butcher 2014). Before the issuance of a valid certificate by a local authority, inspection of the butchery is carried out by an Environmental Health Practitioners (EHPs). This is to ensure that food is prepared, handled, stored and served in a hygienic and safe way.

Although South African EHPs are trained in microbiological analysis of food at first year level, this does not make them competent enough towards proper understanding and interpretation of data they received from microbiologist. Additionally, in some instances, EHP's end up using visual inspections instead of evidence based data because very few local authorities have laboratories. The use of on-site quick and/or instant analysis instruments for detecting possible contaminants in food is currently not in existence.

Conclusions

It can be concluded from literature that there is a serious need to investigate food handlers' way of conducting their daily work routine and the possible sources of microbial contaminants that could affect the quality of meat products. Moreover, pathogenic strains are of great concern in the meat industry as it has been noticed through a number of projects conducted in South Africa and the world at large. In abattoirs and the meat industry in general, the opportunity for contamination of the meat exists, amongst others, from the slaughter floor, throughout the production chain to the retailer, through contact with surfaces and through handling. Therefore it is important that meat processing should be guided by a food safety system, including the schematic layout of the production process so that possible sources of contamination can be identified.

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Table 1: Equipment and utensils commonly used in butcheries

Equipment and utensils	Uses	Prevailing micro-organisms	References
Knives	Used for deboning, cutting, slicing and dicing.	*E. coli and L. monocytogenes*	Rivera-Betancourt *et al*., 2004
Band saws	Sawing through tough muscles, carcasses and cutting of frozen meat.	*Salmonella*, *E. coli* and *L. monocytogenes*	Warriner *et al*., 2002
Bowl cutters	Chops meat into small pieces, thus finely mincing meat, blending and emulsifying proteins.	*S. aureus*	Downes and Ito, 2001
Chopping boards	Used to slice meat.	*Salmonella*, *S.* a*ureus*, *P. aeruginosa* and *Clostridium* spp.	Ak *et al.*, 1994
Meat slicers	Used mainly for cutting ready-to-eat meat into desirable slices.	*L. monocytogenes*	Blackburn and McClure, 2002; Meat Safety Act, 2000 (Act 40 of 2000); American Meat Institute, 2008
Meat grinders	Minces the meat through different discs to a desirable size. Grinding employs torque – a force producing a twisting effect.	*L. monocytogenes*	
Cold room	Used to store chilled meat to prevent growth of microorganisms.	*L. monocytogenes*	
Freezer room	The operating temperature should be -18ºC for freezing the meat.	*L. monocytogenes*	

Table 2: Acts, regulations and standards governing butcheries in South Africa

Act Number, Regulations and Standards	Title	Summary
Act 54 of 1972	Foodstuff, Cosmetics and Disinfectants Act	The act governs all foodstuffs manufactured, processed or sold in South Africa, including those imported into South Africa. In addition, the act requires producers to declare aspects such as food-related allergens and specific ingredients in the product, since consumers rely on the information on the labels to make sensible decisions when purchasing. It also gives the optimal storage temperatures of food.
Act 40 of 2000	Meat Safety Act	In essence, section 12 of regulation R.962 places the responsibility on the butcher to ensure that in the butchery only meat derived in accordance with the Meat Safety Act is handled.
Act 68 of 2008	Consumer Protection Act	Aims to protect and prevent consumers from consuming food products which are hazardous to their health.
SANS 10049:2012	Food Hygiene Management	Covers provisions for the hygienic handling of food and beverages for human consumption, in order to ensure a safe, sound and wholesome product.
Government notice R908 of 2003	Regulations relating to the application of the HACCP System	Specifies the requirements and application for hazards analysis critical control point, which are promulgated under the Foodstuffs, Cosmetics and Disinfectants Act 1972 (Act 54 of 1972).

A review on microbial hazards associated with meat processing in butcheries

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Abstract

Meat is highly nutritional and rich in proteins, which makes it a good substrate for possible microbial growth. As a result, in its raw state meat is easily susceptible to colonisation by microorganisms. This study describes the possible sources of contamination associated with food handlers within butcheries and also microorganisms that are able to contaminate meat and cause a possible variety of illness. It also reflects on knowledge and behaviour of the food handlers, equipment and working surfaces as potential sources of contamination. Meat processing hygiene is part of Quality Management (QM) in abattoirs and butcheries. The QM refers to the hygienic measures taken during various processing stages of meat products. Hence, contamination of meat often caused by food handlers, the production chain and equipment used. Therefore, it was fundamental in this study to identify possible contamination sources and types of microorganisms associated with such meat safety contamination. The latter is important for optimising hygiene practices in butcheries and minimising possible health related risks.

Keywords: equipment, food handlers, foodborne illness, meat hygiene, pathogenic bacterial and possible contamination.

Introduction

Meat safety is a major priority of most meat producers, processors and consumers. This is due to a number of publicised food scares and outbreaks worldwide such as Bovine Spongiform Encephalopathy (BSE), avian flu, foot and mouth diseases, some emerging and/or evolving pathogenic bacteria such as *Escherichia coli* 0157:H7 and *Listeria monocytogenes* (Sofos 2008; Seeiso 2009). Despite the number of meat exports and food safety education offered to meat business operators and processors in South Africa, foodborne illnesses from the consumption of contaminated meat remain a public health concern in developed and developing countries, including South Africa (Griffith 2006; Jacob et al. 2010). In general, meat contamination is associated with inappropriate farming practices. Thus, it is crucial to improve the "farm-to-fork" practices in order to prevent, reduce and/or at least control a number of foodborne diseases related to meat production (Jacob et al. 2010).

In addition to the "farm-to-fork" method, it is important to monitor all aspects of animal husbandry of each farm as part of meat hygiene practices. The monitoring should be aimed at producing safe and healthy livestock. This is significant, given that farm animals are the original source of many foodborne pathogens that cause diseases in humans. However, most animals are asymptomatic; they show no symptoms of illness although their dung and other body fluids remain pathogenically infectious (Ateba et al. 2008; Behravesh et al. 2012). To avoid and control cross contamination, farmers, veterinary and other meat safety related practitioners need to ensure that only healthy animals that are suitable for loading, transportation and slaughter for meat purposes are loaded, transported and processed in abattoirs (Nørrung & Buncic 2008). Therefore, it is important that high levels of hygiene are maintained in any business that handles or processes food and meat for human consumption.

Possible sources of contamination

Raw meat

Literature indicates that the muscle tissue of a healthy living animal is free of microorganisms and the under skin of animal carcass becomes sterile immediately after slaughter (McEvoy et al. 2000). Hence, contamination of raw meat may be due to slaughtering of stressed animals, as well as contact with external surfaces such as hair, gastrointestinal and respiratory tracts and/or other ambient environmental hazards. In the abattoir, contamination occurs with the microorganisms' introduction to direct meat contact with surfaces in operations performed during offloading, weighing, processing, cutting and storage, as well as at the points of sale and distribution (Nørrung and Buncic 2008; Sofos 2008; Ali et al. 2010). Bas et al. (2006) further stated that pathogens are passively transmitted from a contaminated source such as raw poultry to cooked food that is prepared for later consumption as cold foods. Typical microorganisms that are usually prevalent in raw meat include *Listeria monocytogenes*, *Salmonella*, *Staphylococcus aureus*, *Campylobacter* (on poultry), *Escherichia coli* and *Escherichia coli* 0157:H7 amongst others (Ateba et al. 2008).

Food handlers and related hygiene practices

Meat cutting is important in meat processing as carcasses are deboned and cut into smaller and more desirable cuts, using hand tools and machines (Wang and Shanmugam 2009). Hence, the risk of meat becoming contaminated depends largely on the health status of the food handlers, their personal hygiene and knowledge and practice of food hygiene (Collins 2001). According to Nørrung and Buncic (2008), the process of meat handling increases the possibility of microbial contamination because unhygienic practices during handling may lead to transmission of bacteria to the meat from the surfaces. Several studies have further indicated that foodborne illnesses occur due to poor handling of food (Van Tonder 2004; Griffith 2006). *Staphylococcus*-related food poisoning has been linked to food handlers who are known to be carriers of this bacterium (in their skin, infected cuts, nose, throat, etc.) in meat establishments (Van Tonder 2004). In addition, Kusumaningrum et al. (2002) further indicated that various bacteria, amongst others *Staphylococcus aureus, Escherichia coli* and *Salmonella* spp., survive on hands and surfaces for hours or even days after initial contact with the microorganisms.

In addition, 97% of food consumers' illnesses in the USA were linked with improper food handlers' practice in the food-service industry (Bas et al. 2000). Food handlers may on some occasions serve as sources of contamination, especially as a result of some having gastrointestinal illnesses or convalescence process when symptoms have disappeared.

Transportation

Good quality meat with an adequate shelf life can be ensured by the proper maintenance of the cold chain. Hence, South African Regulation 962 of 23 November 2012 framed under the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act no. 54 of 1972) and the Meat Safety Act 2000 (Act no. 40 of 2000) (table 2) clearly reflects and stipulates that all food specified under the regulation and act must be kept at a low temperature or below (4ºC) during storage, transportation and while on display.

In addition, no food may be transported simultaneously with any person or items, or in such a manner that it comes into direct contact with the floor or anything else that can pollute, spoil or contaminate the meat in any way (Van der Walt 2005). Thus, inspection of incoming meat and temperature checks of both the meat and transport used are of principal significance as described in the South African Regulation 962 of 23 November 2012 under the Department of Health (DOH). Therefore, proper transportation of carcasses and meat products together with the maintenance of refrigeration temperatures will reduce the potential for contamination.

Bioaerosols

The microbial contamination of meat and meat products in the past was thought to occur only due to direct contact with contaminated surfaces. However, airborne microorganisms, dust, pollen and mould spores which may be present in ambient air, are contaminants that easily find their way into meat products (Sutton 2004). These airborne contaminants are also known as bioaerosols, and may include bacteria, fungi, viruses, pollen, toxins and other contaminants of non-biological and biological origin (Shale et al. 2004; Nkhebenyane 2010).

Several studies have indicated a range of routes through which microorganisms can be distributed through ambient air during talking, sneezing, coughing and high pressure spraying (Cundith et al. 2002; Shale et al. 2004; Sutton 2004). Furthermore, wastewater, sink and floor

drains, including spilled products that become aerosolised, can also be major sources of bioaerosols causing harm to both the consumer and butchery worker's health. This may possibly lead to the reduction of meat quality, its shelf life and that of other meat products. Therefore, the use of air filtration is of vital importance to ensure fine quality of air in high risk areas such as the preparation and packaging areas, as well as at the purchasing point (Patel 2009). However, such methods do not necessarily prohibit the distribution of bioaerosols in food processing areas.

Biofilms

Biofilms are microbial populations (mainly bacteria) that have the ability to adhere to different surfaces. They are also Extracellular Polymeric Substance (EPS) producers, which are highly hydrated with chemically complex matrix (Hall-Stoodley et al. 2004). The characteristics of EPS are indicated as a reason for the resistance of treated biofilms to sanitising, rather than intrinsic attributes of the cells in the biofilm (Pan et al. 2006).

Studies have illustrated that common sanitation practices are less effective in removing biofilms as compared to free cells (Meyer 2003). The leading causes of the nosocomial infections in the USA, among other countries, are biofilm-related infections sourced by staphylococci (Kong et al. 2006). Studies have also shown that, as in other food sectors, the meat industry is faced with increasing demands in terms of cleaning and disinfection in order to remove microbial coatings such as biofilm which may take days or hours to form (Stopforth at al. 2002). Therefore, the presence of biofilms in the food industry can be a major concern for public health.

Equipment and utensils

Hygienic design features equipment may still become contaminated by microorganisms, workers, bioaerosols and other materials during processing (Evans et al. 2004). Many foodborne disease outbreaks are associated with improperly cleaned utensils and equipment.

According to Gill and McGinnis (2000), meat residues that are not removed from meat contact surfaces during cleaning were indicated to be the primary source of *Escherichia coli* deposited on the meat. *Listeria monocytogenes* is an environmental bacterium which can harbour and thrive in meat processing equipment such as slicers, dicers and machinery for packaging, which are insufficiently cleaned and sanitised (Tompkin 2002; AMI 2008). Table 1 indicates most commonly used equipment and utensils in the butcheries and the prevailing micro-organisms.

[Table 1 here]

ATP (Adenosine Tri-Phosphate) hygiena

The formation of biofilms on equipment and/or utensils is a great concern in the meat industry. With the above in mind, it is then crucial to note that visual inspection is performed in food premises to check equipment used and working surfaces. Thus, it is crucial to use "ATP Hygiena" method to evaluate the cleanliness of working surfaces (Attala & Kassem 2011). Moore et al. (2010) further explained Adenosine Triphosphate (ATP) as an enzyme that is present in all living cells. This method also detects and reflects the amount of organic matter that remains after cleaning an environmental surface, including the equipment. The amount of ATP and where it was detected indicates areas and items in the healthcare setting

that may need to be re-cleaned, and a possible need for improvement in a healthcare facility's cleaning protocols (PIDAC 2012).

As stated before, the primary monitoring of any cleaning programme is visual cleanliness; it involves the assessment of a surface as being free from food debris and other soiling by a person without any sampling aids. This may involve looking at the surface, feeling the surface for any signs of hidden deposits such as grease, oils and even smelling the equipment. In Egypt, most local health departments utilise visual assessments and not microbiological methods, when evaluating the hygiene status of a butchery area in small scale processing plants (Attala and Kassem 2011). However, the use of ATP Hygiena is still lacking and not well documented in some areas, particularly in butcheries.

Public health disease surveillance system and related pathogens

Public health disease surveillance system

In South Africa, food poisoning became a notifiable medical condition in 1990; however, the condition is less likely to be reported due to lack of efficient and integrated foodborne surveillance systems (South Africa, Department of Health 2007). In comparison, internationally, CDC's (Centre for Disease Control) National Notifiable Diseases Surveillance System (NNDSS) utilises a multifaceted Public Health disease surveillance system that gives public health officials powerful capabilities to monitor the occurrence and spread of diseases.

This section of CDC is used by numerous states, territorial, tribal, and local health departments; and by partner organizations such as the Council of State and Territorial Epidemiologists (CSTE), to facilitate, collect, manage, analyse, interpret and disseminate health related data for diseases designated as nationally notifiable. Furthermore, it provides detailed data to CDC programs to aid in identifying specific disease trends, work with states and partners to implement and assess prevention and control programs, and publish summarized data findings weekly and annually in the Morbidity and Mortality Weekly Report (CDC 2014).

Unfortunately, South Africa lacks such a structure and there is a dire need as this system is an effective public health surveillance that must begin at the local- and state health department levels. Moreover, government must work with a variety of healthcare providers, including laboratories, hospitals and private providers, to obtain case reports on many infectious and some non-infectious diseases. Each province must have by laws mandating that providers report cases of certain diseases to province and/or local health departments (CDC 2014).

Pathogenic microorganisms of concern

Whether in raw or processed meat, both usually contain bacteria or other microorganisms. Most of them are harmless whilst some could be a threat to food safety as they are food poisoners. Therefore, principal pathogens of concern are *Staphylococcus aureus, Escherichia coli* 015:H7 (ruminants), *Salmonella* spp. (all meats), *Listeria monocytogenes* (all meats), *Campylobacter jejuni* (poultry) and *Yersinia enterocolitica* (pork) (Kusumaningrum et al. 2002). This microbiota has been associated with food-borne illness outbreaks and even death to many people each year (Borch and Arinder 2002). In addition, the largest outbreak of *E. coli* 0157:H7 occurred in South Wales in 2005 where a total of 157 cases were identified. A

hundred and eighteen of these cases were confirmed positive for *E. coli* 0157:H7 and 31 school children were admitted to the hospital. One death (of a 5-year-old) was reported after consumption of sliced cooked meat and other types of meat supplied by John Tudor and Sons, a catering butchery business (Pennington 2009; Powell et al. 2011).

On the other hand, *Listeria monocytogenes* was reported to have caused an outbreak of food poisoning after consumption of deli meats in Toronto butchery in 2008. The cause of this outbreak was mainly due to trapped meat residues in meat slicing machines which provided a reservoir for *L. monocytogenes* (Pennington 2009). A decade earlier than the latter (during 1999), it was estimated that foodborne pathogens caused 76 million episodes of illness, resulting in 325,000 hospitalisations and 5000 deaths in the United States alone (Osterholm 2011). The Centre for Disease Control and Prevention estimates that there have been approximately 48 million foodborne illnesses, 128,000 hospitalisations and 3000 deaths post 1999 until the 2011 (CDC 2011).

In South Africa as reported by Powell et al. (2011) and Halliday et al. (2012), it remains a challenge to enforce regulations in some sectors due to the lack of surveillance data which results from lack of outbreaks data. This is because of the absence of a CDC system to record the data of outbreaks of foodborne diseases between 1999 and 2010. However, as reported by Sofos (2008), the 1999 estimates cannot be compared with the current ones for purposes of trend analysis due to the fact that different diagnostic methods evolve all the time. Furthermore, the epidemiological data of foodborne illness and surveillance estimated by the U.S. (CDC 2011) such as Food Net and the pathogenic tracking and DNA fingerprinting program (PlusNet) indicated that approximately 60-70% of outbreaks and 40-50% of foodborne illness cases reported remains unresolved as well as the etiologic agent unknown.

Legislation and governance concerned with South African butcheries

Food safety, hygiene legislation

There are laws and regulations in place to secure hygienic conditions and practices to protect the consumers against potential risks of food poisoning (Table 2).

[Table 2 here]

The role of the National Department of Health

The Department of Health's responsibility is to make a contribution to protect South African people from harmful effects of unsafe foods. At a national level, the food control directorate, incorporated in the Chief Directorate, is directly responsible for all matters related to food safety control. In addition, regulation (R.908 of 2003) makes it mandatory for listed food processing institutions to implement HACCP in order to promote food safety and protect public health (South Africa, Department of Health 2003). Although the implementation of HACCP is not mandatory to butcheries, as they are not part of the listed food processing institutions, voluntary adoption of HACCP in all butcheries is encouraged in order to prevent, reduce and/or control meat safety or related hazards and improve the quality of meat and other meat products.

The role of municipality (and EHPs) regarding the butchery

A butchery, by virtue of being a food premises, is required by law to observe all regulations governing food safety and hygienic premises as contained in the Foodstuffs, Cosmetics, Disinfectants Act, 1972 (Act no. 54 of 1972), according to which butcheries are classified as "food premises". Also, "food premises" must comply with the regulations as set out in the Government Notice as R.962 "Regulations Governing General Hygiene Requirements for Food Premises and the Transport of Food".

Once in compliance, butcheries are expected to display valid certificates of acceptability (The Butcher 2014). Before the issuance of a valid certificate by a local authority, inspection of the butchery is carried out by an Environmental Health Practitioners (EHPs). This is to ensure that food is prepared, handled, stored and served in a hygienic and safe way.

Although South African EHPs are trained in microbiological analysis of food at first year level, this does not make them competent enough towards proper understanding and interpretation of data they received from microbiologist. Additionally, in some instances, EHP's end up using visual inspections instead of evidence based data because very few local authorities have laboratories. The use of on-site quick and/or instant analysis instruments for detecting possible contaminants in food is currently not in existence.

Conclusions

It can be concluded from literature that there is a serious need to investigate food handlers' way of conducting their daily work routine and the possible sources of microbial contaminants that could affect the quality of meat products. Moreover, pathogenic strains are of great concern in the meat industry as it has been noticed through a number of projects conducted in South Africa and the world at large. In abattoirs and the meat industry in general, the opportunity for contamination of the meat exists, amongst others, from the slaughter floor, throughout the production chain to the retailer, through contact with surfaces and through handling. Therefore it is important that meat processing should be guided by a food safety system, including the schematic layout of the production process so that possible sources of contamination can be identified.

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Table 1: Equipment and utensils commonly used in butcheries

Equipment and utensils	Uses	Prevailing micro-organisms	References
Knives	Used for deboning, cutting, slicing and dicing.	*E. coli and L. monocytogenes*	Rivera-Betancourt *et al*., 2004
Band saws	Sawing through tough muscles, carcasses and cutting of frozen meat.	*Salmonella*, *E. coli* and *L. monocytogenes*	Warriner *et al*., 2002
Bowl cutters	Chops meat into small pieces, thus finely mincing meat, blending and emulsifying proteins.	*S. aureus*	Downes and Ito, 2001
Chopping boards	Used to slice meat.	*Salmonella*, *S.* a*ureus*, *P. aeruginosa* and *Clostridium* spp.	Ak *et al.*, 1994
Meat slicers	Used mainly for cutting ready-to-eat meat into desirable slices.	*L. monocytogenes*	Blackburn and McClure, 2002; Meat Safety Act, 2000 (Act 40 of 2000); American Meat Institute, 2008
Meat grinders	Minces the meat through different discs to a desirable size. Grinding employs torque – a force producing a twisting effect.	*L. monocytogenes*	
Cold room	Used to store chilled meat to prevent growth of microorganisms.	*L. monocytogenes*	
Freezer room	The operating temperature should be -18ºC for freezing the meat.	*L. monocytogenes*	

Table 2: Acts, regulations and standards governing butcheries in South Africa

Act Number, Regulations and Standards	Title	Summary
Act 54 of 1972	Foodstuff, Cosmetics and Disinfectants Act	The act governs all foodstuffs manufactured, processed or sold in South Africa, including those imported into South Africa. In addition, the act requires producers to declare aspects such as food-related allergens and specific ingredients in the product, since consumers rely on the information on the labels to make sensible decisions when purchasing. It also gives the optimal storage temperatures of food.
Act 40 of 2000	Meat Safety Act	In essence, section 12 of regulation R.962 places the responsibility on the butcher to ensure that in the butchery only meat derived in accordance with the Meat Safety Act is handled.
Act 68 of 2008	Consumer Protection Act	Aims to protect and prevent consumers from consuming food products which are hazardous to their health.
SANS 10049:2012	Food Hygiene Management	Covers provisions for the hygienic handling of food and beverages for human consumption, in order to ensure a safe, sound and wholesome product.
Government notice R908 of 2003	Regulations relating to the application of the HACCP System	Specifies the requirements and application for hazards analysis critical control point, which are promulgated under the Foodstuffs, Cosmetics and Disinfectants Act 1972 (Act 54 of 1972).