Microbial quality of beef and hygiene practices in small and medium slaughterhouses and butcheries in Uganda

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Abstract

Background If hygiene practices along the beef processing nodes at small and medium enterprise (SME) slaughter houses and butcheries are not observed, they may pose a health risk due to microbial contamination. In SME slaughterhouses and butcheries, the risk may be higher due to transmission of foodborne pathogens. This study determined the hygienic practices and microbial quality risk among meat handlers (MH) in SME slaughterhouses and butcheries.

Methods Assessment of microbiological quality of beef was carried out at slaughter houses and butcher shops in the districts of Western, Central and Eastern regions of Uganda. A cross sectional study was conducted from June 2017 to January 2018 using observation checklists to record unhygienic practices among the various actors. Microbial load at slaughter and butchery was determined from a total of 317 swab samples collected from carcass, tools, protective clothing and hands of meat handlers. The microbiological quality of beef was evaluated using standard microbiological methods. The samples were inoculated into differential and selective media.

Results Butcheries had the highest microbial load on beef carcass ranging from 4.76 log 10 cfu/cm² to 7.90 log 10 cfu/cm² Total Viable Counts (TVC) while Total Coliform Counts (TCC) ranged from 1.42 log 10 cfu/cm² to 3.05 log 10 cfu/cm², *E. coli* ranged from 0.68 log 10 cfu/cm² to 1.06 log 10 cfu/cm² and *Staphylococcus aureus* ranged from 3.25 log 10 cfu/cm² to 4.84 log 10 cfu/cm². *Salmonella* was absent in all the samples analysed. Results of overall microbial quality of beef in Uganda indicated that only TCC (1.60±0.26 log 10 cfu/cm²) of the beef carcass samples at slaughter houses was not significantly above the safe level ($p = 0.693$). Overall microbial load (TVC, TCC, *E. coli* and *S. aureus*) at butcheries were significantly ($p < 0.05$) above the safe level. Butcheries of Mbale district had the highest percentage (70%) of beef carcass samples above the TCC safe levels whereas butcheries of Mbarara district had the highest percentage (40%) of beef carcass samples above the *E. coli* safe levels. TVC from hands and clothes at butchery across the three study districts varied significantly ($p=0.007$) with the highest counts (7.23 log 10 cfu/cm²) recorded from personnel clothes and lowest (5.46 log 10 cfu/cm²) recorded from hands. On the other hand, swab samples picked from chopping board and working table at the butchery did not show significant variation in TVC, TCC, *E. coli* and *S. aureus* microbial loads across the three study districts.

Conclusion Hygienic handling of carcasses after slaughter is critical in preventing contamination and ensuring meat safety in informal meat trading sectors in Uganda. Handling practices of beef at Ugandan slaughterhouses and butcheries are not hygienic hence not up to standard and they contribute to microbial contamination of beef posing a risk to consumers. The distribution stage is the most critical period, during which the quality of meat can easily be compromised.

Introduction

In Uganda, beef sector has the highest per capita consumption of all meats and with the highest potential for local and regional growth in demand (Agriterria, 2012). However, handling of beef by actors in the chain from slaughter to butcheries is critical due to cross contamination by microorganisms. Unhygienic handling of beef by butchers and retailers during transportation, storage and improper sanitary conditions at the various retail outlets are leading sources of contamination (Obeng et al., 2013). In the absence of cold chain, the rate of microbial multiplication increases as well as carcass spoilage. Enteric and environmental pathogens that may contaminate the beef during handling along the chain become a risk for foodborne diseases (Assefa et al., 2015).

Hygienic handling of carcasses after slaughter is critical in preventing contamination and ensuring meat safety. The distribution stage (transportation) is the most critical period, especially if the beef is not stored or transported at the right temperature using the recommended containers. When meat is exposed to spoilage microorganisms from processing equipment like cutting knives, chopping tables, transportation containers and personnel, the microorganisms use the meat as a source of nutrients and energy for growth. This is because meat is highly perishable and contains nutrients required for microbial growth (Adams and Maurice, 2008). If hygienic measures are not adhered to in any food handling processes, spoilage and pathogenic microorganisms will come into contact with food and use the food as a source of nutrients to multiply and cause spoilage of the meat and illness to consumers (Assefa et al., 2015). Some of the pathogens associated with foodborne outbreaks include *Staphylococcus aureus* and gram-negative bacilli such as *Salmonella* spp., *Shigella* spp., *Campylobacter jejuni*, enterotoxigenic *Escherichia coli* as well as viral agents like hepatitis A and Norovirus. They have also been associated with food handlers and can survive on hands, skin, mouth, bruises, hair, sponges, clothes, and other surfaces for hours or days after the initial contact (Shojaei et al., 2006).

Beef handling in Uganda is underdeveloped with obsolete food laws and there is currently no institution or authority that is solely responsible for the Food safety in Uganda (Ejalu and Fortin, 2008). As a result, there is failure to develop trade partnerships with countries which have a developed food safety system. Unhygienic food handlers may transmit food borne diseases by cross contamination during storage under inappropriate conditions and also due to use of contaminated equipment (Al Suwaidi et al., 2015). Poor hygiene practices have been identified as contributing factors of food-borne outbreaks (PEH, 2008; Gilbert et al., 2007; Gorman et al., 2002).

The current practices in most of the animal slaughter houses and slaughter slabs in the urban and peri-urban areas in Uganda are non-standardized. For instance, facilities in abattoirs like bleeding rails, craddles, side stores for offal processing, blood pans and sanitary facilities for human use are mostly lacking and there is no separation of operational units. Humans without proper clothing are used to load and offload beef at slaughterhouses and butcheries. At the butchery, most premises are not made to specifications of selling meat products. There is no observation of hygiene in slaughterhouses due to lack of facilities like fly traps, water taps, water, sterile knives, washing basins and offal safes. At the butchery, equipment like chopping boards, tables and knives are never sanitized.

Practices of meat handling under conditions where such facilities are non-existent in a beef value chain poses a big challenge in meat safety and quality. Therefore, this study assessed the microbiological quality of beef at small and medium slaughter houses and butcheries in Uganda.

Materials And Methods

Study Area

A cross sectional survey was carried out among SME slaughter houses and butcheries in major districts of Western, Central and Eastern regions of Uganda. These included districts of Mbarara (in Western region), Kampala (in Central region) and Mbale (in Eastern region) in Uganda (Fig. 1).

Target actors and sampling technique

A total of three hundred and seventeen (317) surface swab samples were collected from 42 facilities i.e. 4 slaughter houses and 10 retail meat outlets (butchery) from each of the three study districts of Mbarara, Kampala and Mbale as shown in Fig. 1. All the actively operating slaughter houses and butcheries (working daily) in Mbarara were purposively sampled. Similar number of facilities i.e. slaughter houses and butcheries were randomly sampled in Mbale and Mbarara using the same inclusion criteria. The swab samples were obtained from the hands and clothes of personnel, tools (Machete, Knives), surfaces (working tables, chopping board, floor) as shown in Table 1 and carcass (Table 2).

Sample collection and preparation

The surface swabs were aseptically collected from slaughter houses and butcheries. For surface swabbing, an area of approximately 10cm² was sampled by rolling and rubbing a sterile moist swab with the aid of a template (Microgen, 2016) from hands, surfaces of working benches, carcass, cutting tools or equipment and chopping boards. Swabs were collected from carcass, hands, clothes, working tables, cutting tools or equipment and chopping boards. The swabs were transferred into sterile transport medium (STUARTS), labelled and then placed in a cool box lined with ice packs awaiting transportation to the laboratory for examination (Da Silva et al., 2013). Observation check list was used to record unhygienic practices at slaughter houses and butchery.

Determination of Microbial load

Total Viable Counts: Microbiological analysis was carried out using standard methods (APHA, 2001; Adams and Maurice, 2008). The sample was inoculated by surface spreading onto standard Plate Count Agar (PCA). Serial 10-fold dilutions up to 10⁻⁸ were prepared. Dilutions of each sample were inoculated in duplicate in the standard plate count agar medium just before solidification of the agar. On solidification of agar, the plates were incubated at 37°C for 24 hours. After 24 hours of incubation, the colonies were counted using colony counter.

Total Coliforms Counts: The sample was inoculated by surface spreading onto Violet Red Bile Agar (VRBA) and incubation done at 37°C for 24-48 hours. Pink colonies were observed, counted and expressed in colony forming units (CFU) per cm².

***Escherichia coli*:** The sample was inoculated by surface spreading onto Violet Red Bile Agar (VRBA) and incubated at 45°C for 24-48 hours. Blue/violet colonies were observed and counted and expressed in colony forming units (CFU) per cm².

***Staphylococcus aureus*:** The sample was inoculated on Mannitol Salt Agar (Oxoid, UK) by surface spreading and the plates were incubated aerobically at 37°C for 24-48 hours.

***Salmonella enterica*:** To the surface swabs aseptically collected, 90ml of 1% sterile peptone saline was added. The sample was incubated at 37°C for 24 hours (pre-enrichment phase). 1ml of the inoculum was placed in 10ml of Rappaport-Vassiliadis broth (selective enrichment phase) and incubated at 42°C for 24 hours. The resulting sample was inoculated on Xylose Lysine Dextrose (XLD) (Oxoid, UK) and incubated at 37°C for 24-48 hours. Plates were read to look for brown, grey, green or black colonies with metallic sheen, colourless colonies with/without black centres. Selective plating was done on Tripple Sugar Iron (TSI) Agar (Oxoid, UK) slants and urea agar slant and incubated at 37°C for 24-48 hours. Observation was done by looking for a red slant and yellow butt at times black spots on TSI slant. Then a pale-yellow slant on the urea agar slant was observed with the slide, and for agglutination test, suspect the salmonella colony with the poly 'o' salmonella antisera.

Data Analysis

Data was analyzed using descriptive statistics and presented as Mean ± Standard Error of mean (SEM). Variations in the mean microbial counts among the three districts were also determined using one-way ANOVA and consequently least-significant difference (LSD) post hoc test for multiple comparison. One sample t test was used to compare the overall microbial counts with microbial limit set by FAO/WHO. Independent samples t-test was used to test variations in microbial counts in slaughter houses and butcheries. Statistical analysis was run in SPSS ver. 20 (IBM Corp. Armonk, NY: Released 2011) at 5% level of significance. Graphs were plotted using Microsoft excel ver. 2016.

Results

Mean microbial load ($\log_{10}\text{cfu}/\text{cm}^2$) in Carcass at slaughter and butchery

Fig 2 shows the mean microbial counts of carcass surface swabs collected from slaughter houses and butcheries (meat selling points). Mbarara district presented the highest TVC at both slaughter houses and butcheries with mean values of 6.17 ± 0.58 and $7.90 \pm 0.63 \log_{10}\text{cfu}/\text{cm}^2$ respectively. Statistical analysis indicated a significant difference in the TVC of meat samples across the three districts at both slaughter houses ($p = 0.020$) and butcheries ($p = 0.000$). Mbale District had the highest TCC of 2.10 ± 0.40 and $3.05 \pm 0.22 \log_{10}\text{cfu}/\text{cm}^2$ at slaughter houses and butcheries respectively as compared to other districts. However, TCC did not vary significantly at both slaughter houses ($p = 0.462$) and butcheries ($p = 0.108$) across the three Districts. Samples from slaughter houses and butcheries of Mbarara district also had high *E. coli* counts of 0.71 ± 0.32 and $1.06 \pm 0.43 \log_{10}\text{cfu}/\text{cm}^2$ respectively compared to other Districts. Nonetheless, the variations were not statistically significant across the three Districts. Butcheries of Mbarara and slaughter houses of Mbale recorded the highest counts of *S. aureus* with mean values of 4.84 ± 0.33 and $3.72 \pm 0.57 \log_{10}\text{cfu}/\text{cm}^2$ respectively. However statistical analysis indicated significant variation at only butcheries across the three districts ($p = 0.000$).

Fig 3 shows the overall mean microbial load of surface swabs collected from hands, tools and personnel clothing at slaughter houses and butcheries (meat selling points) in Uganda based on overall samples collected from the three Districts. Personnel clothing from butcheries presented the highest TVC and *S. aureus* microbial load of 7.23 ± 0.55 and $4.56 \pm 0.54 \log_{10}\text{cfu}/\text{cm}^2$ respectively. On the other hand, machete at slaughter houses had the highest TCC and *E. coli* loads of 2.43 ± 0.28 and $0.73 \pm 0.25 \log_{10}\text{cfu}/\text{cm}^2$ respectively. However statistical analysis indicated significant variation in TVC ($p = 0.003$) and *S. aureus* ($p = 0.009$) loads from machete, TVC ($p = 0.007$) and TCC ($p = 0.016$) loads from personnel clothing across the two nodes of the beef value chain. Samples from hands and knives did not vary significantly in microbial load across the two nodes of the beef value chain. *Salmonella enterica* was absent in all the samples analysed.

Microbial counts ($\log_{10}\text{cfu}/\text{cm}^2$) from tools, surfaces, personnel hands and clothes at slaughter and butchery

Comparison of the microbial load from tools, surfaces, personnel hands and protective clothing in the three districts (Table 1) was as follows: Generally, swab samples from butchery operators had higher microbial load than slaughter house operators across the three districts.

On overall (all districts), personnel clothes of butchery operators had a significantly higher microbial load of TVC and *S. aureus* than hands, machete, knives, chopping board and working table ($p=0.000$ and $p=0.001$ respectively).

Personnel clothes of butchery operators from Mbarara district presented the highest TVC and *S. aureus* loads of 8.38 ± 0.28 and $5.05 \pm 0.71 \log_{10}\text{cfu}/\text{cm}^2$ respectively compared to Mbale and Kampala districts.

Furthermore, butchery operators indicated high TCC microbial load ($3.82 \pm 0.60 \log_{10}\text{cfu}/\text{cm}^2$) from machete in Mbale district whereas clothes had high *E. coli* microbial load ($1.91 \pm 0.65 \log_{10}\text{cfu}/\text{cm}^2$) in Kampala. On overall, all swab samples indicated that Mbarara district had the highest TVC and *S. aureus* microbial load than Kampala and Mbale ($p=0.000$) at the butchery.

At slaughter houses, the highest microbial load was recorded for TVC ($8.32 \pm 0.27 \log_{10}\text{cfu}/\text{cm}^2$) and *S. aureus* ($4.96 \pm 0.73 \log_{10}\text{cfu}/\text{cm}^2$) from personnel protective clothing in Mbarara district where as Mbale district had the highest TCC loads of $2.97 \pm 0.18 \log_{10}\text{cfu}/\text{cm}^2$ and Kampala District presented the highest *E. coli* loads of $1.79 \pm 0.62 \log_{10}\text{cfu}/\text{cm}^2$.

On overall (all districts), floors of slaughter houses had a higher microbial load of TVC whereas *S. aureus* microbial load was high in machete but did not vary significantly ($p<0.05$). Generally, all swab samples indicated that Mbarara district had the highest TVC and *S. aureus* microbial load than Kampala and Mbale ($p=0.000$) at the slaughter houses but *E. coli* was highest in Kampala ($p=0.001$). Pairwise comparisons of the microbial loads between districts and swab samples are shown in table 1.

Comparison of overall microbial quality of beef in Uganda with quality standards

Table 2 summarizes the microbiological limits based on standards provided by (FAO/WHO, 2003; Codex, 2011; EC, 2018). Results indicated that at slaughter houses in Uganda only TCC ($1.60 \pm 0.26 \log_{10}\text{cfu}/\text{cm}^2$) of the beef samples was not significantly different from the safe level ($p = 0.693$). Beef samples at butcheries were all significantly above the satisfactory (safe) level. Results in Fig. 4 further indicate that butcheries generally had a higher proportion of samples that did not conform to safe microbial levels than slaughter houses across the three districts. All carcass samples at butcheries from the three districts did not conform to the *S. aureus* safe levels. Butcheries in Mbale district had the highest percentage (70%) of beef samples above the TCC safe levels whereas butcheries of Mbarara district had the highest percentage (40%) of beef samples above the *E. coli* safe levels. However, Mbarara and Kampala recorded the highest percentage (80%) of beef samples above the TVC safe levels.

Compliance of slaughter houses and butchery based on good practices

Slaughter house and butchery establishments were assessed for compliance to standard operating practices through non participatory observations and the results are recorded in table 3. The results indicate that the butcheries were less compliant (14-33%) to the good operating practices as compared to slaughter houses (40-80%) in the study area. Observation results revealed that floors were dirty, knives and other cutting tools were handled carelessly, weighing scales were unclean and all the butchery establishments lacked hand washing facilities. Observations made on handling of tools by slaughter operators showed that knives were kept in gum boots during the slaughter process. In all the study areas, the slaughter houses were found to carry out meat inspection by visual assessment. When these results from observation survey were compared with the microbial data results, it was established that butcheries had the highest microbial load compared to slaughter houses.

Discussion

Mean microbial load ($\log_{10}\text{cfu/cm}^2$) in Carcass at slaughter and butchery

The higher microbial counts for TVC, TCC, *E. coli* and *S. aureus* in the carcass swabs obtained from the butcher shops (meat retail shops) than at slaughter houses showed that level of contamination in the meat shops was higher compared to the abattoir and these results relate to Bhandare et al. (2007). In another study in Kampala Uganda by Bogere & Baluka (2014) contamination of meat with Coliforms and *E. coli* was higher at the butchery level than at the abattoir level. The higher microbial load at the butcheries is attributed to beef that is displayed mixed with offals openly on tables, structures with no screens hence attracted flies into the butcheries. Furthermore, the higher microbial load at the butchery relates to the results from observation where floors were found dirty, knives and other cutting tools were handled carelessly, weighing scales were unclean and all the butchery establishments lacked hand washing facilities. Related studies indicate that the beef can be subjected to contamination from a variety of sources from within and outside the animal both at slaughter, transport and sale (Kumar et al., 2014; Adams & Maurice, 2008). At slaughter, meat inspection covers only visual assessment, without considering microbiological tests (Rani et al., 2017) and this was similar to all the slaughter houses in all the study districts and microbial contaminated meat can end up being sold and hence made available to the consumers. Additionally, when meat is exposed to microorganisms which may be present on cutting knives, chopping tables and other equipment, it leads to spoilage thereby reducing the shelf life and quality of meat (Adzitey and Huda, 2012).

Microbial counts ($\log_{10} \text{cfu/cm}^2$) from tools, surfaces, personnel hands and clothes at slaughter and butchery

The high microbial load in tools could be attributed to unhygienic handling at slaughter and this favours cross contamination. For example, from observations of the handling of tools by slaughter operators (butcher men), the knives were kept in gum boots during the slaughter process. In a study in Algeria, it was noted that during evisceration, unhygienic workers' behaviours make use of tools that have been in direct contact with skin and faeces of the animals at the slaughtering halls (Nouichi and Mossadak, 2009). Studies have reported that at the abattoir, the potential health risk to consumers is brought about by the presence of pathogens in meat and contaminated equipment (Birhanu et al., 2017). Microorganisms like *Escherichia coli*, *Staphylococcus aureus* and *Salmonella spp* are known to survive on surfaces for hours or days (Pérez-rodríguez et al., 2013) and so prevention of formation of biofilms on meat cutting equipment will prevent them from becoming media of cross-contamination among carcasses (Wambui et al., 2017).

At the butchery, besides using knives to cut meat, they are also used to scrap off chipped meat on tables (Chepkemai et al., 2015) and other surfaces for example chopping stump or board. The high microbial loads on knives and machete recorded at the butchery in this study may be attributed to unsterilized knives and the unhygienic usage. A study by Chepkemai (2016) found out that majority of butchery operators could be wiping the knives with a piece of cloth instead of washing according to Sanitation Standard Operating Procedures (SSOPs). During observations, different butcheries which operate close to each other were sharing cutting tools (knives and machete) among themselves and this could be a possible source of contamination. The carcass can get exposed to spoilage microorganisms during cutting and they may be present on cutting knives and other equipment. These microorganisms cause spoilage thereby reducing meat shelf life and its quality (Adzitey and Huda, 2012). Higher mean log values in the abattoir and butcher shops was also reported in a study (Birhanu et al, 2017), but was highest in butchery tools. The high microbial load on the knife is an indication of an inadequate cleaning and continuous use of a single knife despite contact with dirty or contaminated material surfaces (Birhanu et al., 2017). Research has shown that when contaminated equipment is used continuously for a long period of time, microorganisms initially present can multiply and act as a continuous source of contamination in the food produced subsequently (Ray, 2005).

The highest microbial load in personnel hands and clothes was found in butcher shops and this is similar to a study by Kebede et al. (2014). The higher TVC count in personnel hands and clothes can be attributed to lack of awareness by the butchery operators on good hygiene practices (Kebede et al., 2014) and hence unhygienic handling (Obeng et al., 2013). For example, handling money while serving food increased microbial contamination (Muinde and Kuria, 2005). In a study by Birhanu et al. (2017) the high microbial load in workers hands in the butcher was due to the fact that they handled money at the same time meat. The same hands were used to contact their hair, shake hands with friends or customers and absence of hand washing before and after serving meat to customers.

The mean TVC and TCC from personnel hands and clothes were highest at the butchery than at slaughter. A similar study found out that the mean bacterial load was higher at the butchery level than at the abattoir (Bogere and Baluka, 2014). Observations indicated low adherence of butcher men in wearing protective clothing and the same people who handled meat received money and these could be the reasons of high microbial load contamination at butcheries (Chepkemoi et al., 2015). In a related study, hands were found to be a major source of infection from microorganisms in food stuffs (Kahraman et al., 2010). The butcheries were located along the road side and this exposed the meat to dust raised by automobiles (Bogere and Baluka, 2014). In the study, several butcheries were located next to each other and the butcher men shared weighing scales, stones and cutting tools and besides the microbial load increased with longer stay of meat at the butchery (Obeng et al., 2013). Some butcheries share refrigerators with retail shops hence meat is kept with other commodities such as beverages, water and other ready-to-eat foods (Mirembe et al., 2015) and this can be a source of contamination.

Slaughtering was done on the floor in all the slaughter houses in the study area and this way of handling animals on the slaughter floor can affect the quality of meat (RMAA, 2011). The animals were dragged into the slaughter house and slaughtered from the floor. They are even made to see carcasses of previously slaughtered animals which are a violation to animal rights and welfare (Fasae and Bakare, 2016). The floor was often dirty and with spills of blood from previous slaughter activity and this could be the reason why the slaughter floors were highly contaminated. Slaughtering and processing of carcass in the study areas was done on the floor of the slaughter house and this was usually contaminated from previous activities and hence potential source of microbial contamination. In another study, it was reported that flaying, evisceration and splitting of carcass were carried out on unhygienic floors and such practices increase chances of carcass contamination and leading to unsafe meat (Lawan et al., 2013).

Surfaces at the butchery include chopping board and working table where meat and offals are displayed. The high microbial loads on working tables and chopping boards at butchery were similar to the findings of (Chepkemoi, 2016) who observed that contamination of meat can occur during selling where surfaces like tables and chopping boards are contaminated.

Cleaning slaughter floor with cold water is unsatisfactory and if there was a supply of hot portable water in abattoirs, it would remove fatty nature of wastes at the abattoir. Additionally, washing with hot water and detergent facilitates easy and quality washing of abattoir floor (Lawan et al., 2013) and surfaces at the butchery. In Kenya, meat was found to be contaminated with microbial pathogen like *E.coli* and *S. aureus* due to poor handling practices post-slaughter and poor personnel hygiene (Chanzu et al., 2018) and the same applies to the current study.

From observations of slaughter operators, the protective clothing worn are very dirty and yet during meat carriage, the carcass comes into contact with them. This could be due to the fact that protective clothing worn at the slaughter houses are rarely cleaned and so harbour a lot of microorganisms. Additionally, the microbial load in clothes and hands could result from carcass contamination at the slaughter houses that comes from a variety of sources within and outside animal during the slaughter process. The contaminating organisms come mainly from the hide of the animal and the faeces (Kumar et al., 2014). For example in a study in Juba town-South Sudan, it was found out that slaughter operators do not wear protective clothing and sometimes, the men remove their shirts during the process (Andrea and Aburi, 2012). Generally, the high mean values of microbial load is as a result of poor handling of meat at the slaughtering places (Kebede et al., 2014). Moreover, poor hygienic practices expose food products to microbial contamination which reduce the shelf life and affect public health (Mwangi et al., 2016).

Microbiological Contamination Of Carcass Samples Limits

Carcass samples that fall in unsatisfactory levels are above expected microbiological levels and indicate poor food handling practices (Food standards Australia Newzeland, 2018). The presence of *E. coli* (faecal indicator organism) in the beef indicates direct or indirect faecal contamination and this suggests a general lack of cleanliness in handling and improper storage (Centre for Food safety, 2014). Research indicates that microbial contamination occurs at every phase of processing but can be reduced through use of proper sanitation equipment and personal hygiene (Maharjan et al., 2019). Results indicated high prevalence of *S. aureus* in the carcass and relates to several studies that documented prevalence of *S. aureus* in many raw retail meats; an indication that consumers are at potential risk of *S. aureus* colonization and subsequent infection. Staphylococcal food-borne disease (SFD) is one of the most common food-borne diseases worldwide resulting from the contamination of food by preformed *S. aureus* enterotoxins (Kadariya et al., 2014; Das and Mazumder, 2016). Eventually, the microbial contaminated meat will lead to morbidity and mortality (Abdullahi et al., 2016) among the consumers if there is continuous non-compliance to Standard Operating Practices.

Conclusion

Observations indicated that the protective clothing worn by different actors were dirty and yet during meat carriage, the carcass comes into contact with them. Dirty protective clothing worn harbour a lot of microorganisms and this is a source of microbial contamination. For the surface swabs, the floor had the highest microbial counts compared to working table and chopping board/stamp. The fact that surfaces at the butchery like chopping board are never cleaned apart from scrapping off dirt using a knife, they act as micro-habitats for the microorganism. The carcass can get exposed to spoilage microorganisms during cutting which may be present on cutting knives and other equipment. Hygienic handling of carcasses after slaughter is critical in preventing contamination and ensuring meat safety in informal meat trading sectors in Uganda. Handling practices of beef at Ugandan slaughterhouses and butcheries are not hygienic hence not up to standard and they contribute to microbial contamination of beef posing a risk to consumers. The distribution stage is the most critical period, during which the quality of meat can easily be compromised. Generally, the butcher shops showed highest microbial contamination than slaughter houses. Therefore, actions are required to re-establish effective beef handling controls right from slaughter.

Declarations

Ethical approval

The research was approved by National ethics committee (Uganda National Council of Science and Technology (RELOAD/A401 UNCST 2012) and the University Research Ethics Committee (04/09–17).

Availability of data and materials

The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Authors' contribution

This research work was part of Juliet Kyayesimira thesis research for the award of PhD in Biological Sciences of Mbarara University of Science and Technology. The research work was supervised by Grace Kagoro Rugunda, Lejju Julius Bunny & Joseph W. Matofari. Juliet Kyayesimira was in-charge of administering observation checklists, sample collection and laboratory analysis while Dr. Morgan Andama and Wangalwa Rapheal were in charge of technical guidance during data analysis and manuscript review. All authors have been involved in the research design, data analysis, interpretation of results and manuscript writing. The authors have read and approved the final manuscript.

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Tables

Table 2: Overall microbial quality (Mean±SEM) of beef (Carcass) in Uganda

Microbial Parameter	Overall microbial load (log (cfu/cm ²))		Microbial limits		
	Slaughter House (n = 34)	Butchery (n = 30)	Satisfactory (safe level) (log (cfu/cm ²))	Acceptable (log (cfu/cm ²))	Unsatisfactory level (log (cfu/cm ²))
	Mean±SEM	Mean±SEM			
TVC	5.32±0.30*	6.05±0.34*	< 3.5	3.5-5	> 5.0
TCC	1.60±0.26	2.40±0.23*	<1.5	1.5-2.5	> 2.5
<i>E. coli</i>	0.58±0.18*	0.86±0.22*	0	0	> 0
<i>S. aureus</i>	3.21±0.30*	4.02±0.17*	<2.0	2-3	>3

*values significantly above the satisfactory (safe level) following one sample t test (p < 0.05). Microbiological limits are based on FAO/WHO, Codex alimentarius Commission: Report No.: CX/NEA 03/16 and Report No.: 5996 and European Commission Report No. 2073/2005; TVC (Total viable count) - Aerobic colony count; TCC (Total Coliform Count)- **Enterobacteriaceae**

Table 1: Mean± SEM for Microbial counts (log₁₀cfu/cm²) from tools, surfaces, personnel hands and clothes at slaughter and butchery in Study Districts

		TVC		TCC		<i>E. coli</i>		<i>S. aureus</i>	
		SL	BT	SL	BT	SL	BT	SL	BT
Mbale (nS=45, nB=48)	Hands (nS=10, nB=5)	3.99± 0.33 ^{i,a}	5.38±0.45 ^{i,b}	0 ⁱ	2.19±0.95 ⁱ	0	0.40±0.40 ⁱ	2.65± 0.14 ^{i,c}	3.41±0.48 ^{i,c}
	Clothes (nS=15)	3.30± 0.17 ⁱⁱ	-	2.97±0.18 ⁱⁱⁱ	-	-	-	3.05± 0.11 ⁱ	-
	Machete (nS=5, nB=5)	4.71± 0.20 ^{i,d}	5.66±0.42 ^{i,d}	2.98± 0.22 ^{iii,e}	3.82±0.60 ^{i,ii,e}	0	0.66±0.66 ⁱ	3.60± 0.35 ^{i,f}	4.57±0.64 ^{i,f}
	Knives (nS=12, nB=10)	4.18± 0.11 ^{i,g}	4.16±0.11 ^{ii,g}	1.52± 0.54 ^{ii,h}	1.34±0.55 ^{i,h}	0	0 ⁱ	2.50±0.70 ^{i,j}	2.29±0.65 ^{i,ii,j}
	CB (nB=10)	-	4.16±0.17 ⁱⁱ	-	3.13±0.27 ^{i,ii}	-	0.68±0.35 ⁱ	-	2.57±0.44 ^{i,ii}
	WT (nB=18)	-	4.55±0.28 ^{i,ii}	-	2.55±0.26 ^{i,ii}	-	0.22±0.15 ⁱ	-	3.58±0.19 ⁱ
	Floor (nS=3)	4.59±0.13 ⁱ	-	2.68±0.21 ^{ii,iii}	-	2.10±0.10	-	2.69±0.35 ⁱ	-
Mbarara (nS=31, nB=56)	Hands (nS=8, nB=10)	5.74±0.58 ^{i,k}	6.28±0.69 ^{i,k}	0.69±0.45 ^{i,l}	1.15±0.51 ^{i,iii,l}	0.54±0.35 ^{i,m}	0.48±0.32 ^{i,ii,m}	4.37±0.33 ^{i,n}	4.45±0.43 ^{i,n}
	Clothes (nS=8, nB=8)	8.33±0.27 ^{ii,o}	8.38±0.28 ^{ii,o}	0 ⁱ	0 ⁱ	0 ^{i,ii}	0 ⁱ	4.96±0.73 ^{i,p}	5.05±0.71 ^{i,p}
	Machete (nS=7, nB=10)	5.68±0.78 ^{i,q}	6.33±0.64 ^{i,q}	1.86±0.66 ^{ii,r}	1.98±0.58 ^{i,ii,iii,r}	1.25±0.45 ^{i,s}	0.78±0.40 ^{i,ii,s}	3.71±0.42 ^{i,t}	4.18±0.33 ^{i,ii,t}
	Knives (nS=4, nB=10)	6.99±0.67 ^{i,ii,u}	5.79±0.60 ^{i,u}	0 ⁱ	2.03±0.58 ^{i,ii,iii}	0 ^{i,ii}	0.83±0.34 ^{i,ii}	3.45±1.26 ^{i,v}	3.04±0.41 ^{i,v}
	CB (nB=8)	-	7.02±0.62 ^{i,ii}	-	2.52±0.57 ^{i,ii}	-	1.15±0.44 ^{i,ii}	-	4.77±0.18 ⁱ
	WT (nB=10)	-	6.50±0.55 ⁱ	-	1.03±0.43 ^{i,iii}	-	0.43±0.29 ^{i,ii}	-	3.61±0.67 ^{i,ii}
	Floor (nS=4)	6.77±0.53 ^{i,ii}	-	2.35±0.13 ⁱⁱ	-	0 ^{i,ii}	-	4.15±0.03 ⁱ	-
Kampala (nS=23, nB=50)	Hands (nS=6, nB=10)	4.42±0.49 ^{i,iii,w}	4.70±0.28 ^{i,w}	0 ⁱ	0.77±0.40 ⁱ	0 ⁱ	0 ⁱ	2.40±1.08 ^{i,x}	3.35±0.28 ^{i,x}
	Clothes (nS=4, nB=4)	4.84±0.61 ^{i,iii,y}	4.93±0.58 ^{i,ii,y}	2.02±0.69 ^{ii,z}	2.08±0.70 ^{i,z}	1.79±0.62 ^{ii,A}	1.91±0.65 ^{ii,A}	3.41±0.62 ^{i,B}	3.60±0.56 ^{i,ii,B}
	Machete (nS=6, nB=10)	3.36±0.12 ^{i,iii,C}	6.19±0.38 ^{ii,D}	2.65±0.10 ^{ii,E}	1.80±0.40 ^{i,E}	0.72±0.46 ^{i,ii}	0 ⁱ	0 ⁱⁱ	3.34±0.62 ⁱ
	Knives (nS=3, nB=6)	4.52±0.52 ^{i,iii,F}	4.29±0.32 ^{i,F}	1.93±0.99 ^{ii,G}	1.44±0.65 ^{i,G}	1.49±0.76 ^{ii,H}	1.18±0.53 ^{iii,H}	1.17±1.17 ^{i,ii,I}	1.69±0.75 ^{ii,I}
	CB (nB=10)	-	5.30±0.40 ^{i,ii}	-	1.37±0.38 ⁱ	-	0 ⁱ	-	3.62±0.36 ⁱ
	WT (nB=10)	-	3.77±0.42 ⁱ	-	1.05±0.44 ⁱ	-	0 ⁱ	-	1.83±0.51 ⁱⁱ
	Floor (nS=4)	6.35±0.56 ⁱⁱ	-	2.80±0.04 ⁱⁱ	-	1.58±0.53 ⁱⁱ	-	3.67±0.88 ⁱ	-
All swabs	Mbale (nS=45, nB=48)	3.93±0.12 ^{i,j}	4.59±0.15 ^{i,k}	1.90±0.24 ^{i,L}	2.51±0.22 ^{i,L}	0.14±0.08 ^{i,M}	0.34±0.12 ^{i,M}	2.85±0.20 ^{i,N}	3.18±0.21 ^{i,N}
	Mbarara(nS=31, nB=56)	6.69±0.32 ^{ii,O}	6.65±0.26 ^{ii,O}	0.90±0.24 ^{ii,P}	1.47±0.22 ^{ii,P}	0.42±0.16 ^{i,Q}	0.61±0.14 ^{i,Q}	4.23±0.28 ^{ii,R}	4.13±0.21 ^{ii,R}
	Kampala(nS=23, nB=50)	4.57±0.28 ^{i,S}	4.90±0.19 ^{i,S}	1.78±0.28 ^{i,T}	1.34±0.19 ^{ii,T}	0.97±0.24 ^{ii,U}	0.29±0.11 ^{i,V}	2.01±0.45 ^{iii,W}	2.92±0.23 ^{i,X}
All districts	Hands (nS=24, nB=25)	4.68±0.30 ^{i,Y}	5.46±0.33 ^{i,Y}	0.23±0.16 ^{i,Z}	1.21±0.32 ^{i,A}	0.18±0.12 ^{i,B}	0.27±0.15 ^{i,B}	3.16±0.33 ^{i,ii,C}	3.80±0.24 ^{i,C}
	Clothes (nS=27, nB=12)	5.02±0.46 ^{i,ii,D}	7.23±0.55 ^{ii,E}	1.95±0.29 ^{ii,iii,F}	0.69±0.36 ^{i,ii,G}	0.26±0.15 ^{i,ii,H}	0.64±0.33 ^{i,H}	3.67±0.28 ^{i,I}	4.56±0.54 ^{i,I}
	Machete (nS=18, nB=25)	4.64±0.38 ^{i,j}	6.14±0.30 ^{i,ii,K}	2.43±0.28 ^{ii,L}	2.28±0.34 ^{ii,L}	0.73±0.25 ^{ii,iii,M}	0.44±0.21 ^{i,M}	2.44±0.46 ^{i,ii,N}	3.92±0.31 ^{i,O}
	Knives (nS=19, nB=26)	4.82±0.31 ^{i,ii,P}	4.82±0.28 ^{i,P}	1.26±0.39 ^{iii,Q}	1.63±0.33 ^{i,ii,Q}	0.24±0.16 ^{i,ii,R}	0.59±0.20 ^{i,R}	2.49±0.54 ^{i,ii,S}	2.44±0.35 ^{ii,S}
	CB (nS=0, nB=28)	-	5.39±0.32 ⁱ	-	2.33±0.27 ⁱⁱ	-	0.57±0.19 ⁱ	-	3.57±0.26 ⁱ
	WT ((nS=0, nB=38)	-	4.86±0.28 ⁱ	-	1.76±0.23 ^{i,ii}	-	0.22±0.10 ⁱ	-	3.13±0.26 ^{i,ii}
	Floor (nS=11, nB=0)	6.02±0.38 ⁱⁱ	-	2.60±0.09 ⁱⁱ	-	1.15±0.33 ⁱⁱⁱ	-	3.58±0.35 ^{i,ii}	-

Key: - Not sampled; SL-Slaughter house, BT- Butchery, nS- number at slaughter, nB- number at butchery, TVC- total viable counts, CB-Chopping board, WT- Working table. TCC- Total coliform counts. Mean values with different letters in the same row (i.e. **comparison of** microbes in SL &BT) and mean values with different roman numbers in the same column (i.e. **comparison of** microbes in tools, surfaces, personnel hands and clothes as well as across districts) are significantly different (p<0.05).

Table 3: Compliance requirements for slaughter houses and butchery establishments

Slaughter house establishments			
Good practices	Kampala (n=5)	Mbarara (n=4)	Mbale (n=4)
Lairage	5 (100%)	1 (25%)	1 (25%)
Slaughter hall	5 (100%)	4 (100%)	4 (100%)
Rail system	5 (100%)	1 (25%)	1 (25%)
Gut & tripe room	5 (100%)	0	0
Cold room/Carcass chilling area	5 (100%)	0	0
Easy to clean surface floor	5 (100%)	4 (100%)	4 (100%)
Detained meat room	2 (40%)	0	0
Incinerator for condemned meat	1 (20%)	1 (25%)	1 (25%)
Cutting room	5 (100%)	4 (100%)	4 (100%)
Drainage system	3 (60%)	1 (25%)	1 (25%)
Adequate ventilation	5 (100%)	4 (100%)	4 (100%)
Portable Water supply	5 (100%)	1 (25%)	1 (25%)
Electricity supply	5 (100%)	1 (25%)	1 (25%)
Toilet facilities	5 (100%)	1 (25%)	1 (25%)
Changing room	5 (100%)	1 (25%)	1 (25%)
% compliance of slaughter houses	88	40	40
Butchery establishments			
Number of butcheries abiding with requirements			
Good practices	Kampala (n=18)	Mbarara (n=18)	Mbale (n=15)
Availability of water	2 (11%)	0	0
Ambient meat storage	3 (17%)	0	0
Insect proof window & doors	3 (17%)	0	0
Stainless steel tools	18 (100%)	18 (100%)	15 (100%)
Availability of preparation room	3 (17%)	0	0
Easy to clean sales counter	8 (44%)	0	5 (33%)
Waste disposal point	8 (44%)	2	4 (27%)
Standard butchery structure	3 (17%)	0	0
% compliance at the butchery	33	14	20

Key: (0) indicates no compliance and (n) indicates the number of butcheries/slaughter houses visited

Figures

Figure 1

Map of Uganda showing the study Districts (BT=Butchery, SL=Slaughter house).

Figure 2

Mean $\pm$ SEM Microbial load in carcass at slaughter house (H.) and butchery

Figure 3
Comparison of overall microbial load on hands, tools and personnel protective clothing at slaughter house (H.) and butchery. All data are presented as mean±SEM

Figure 4
Percentage of carcass samples above the expected microbial safe levels