Tanzania Journal of Health Research https://dx.doi.org/10.4314/thrb.v24i4.14
Volume 24, Number 4, October 2023

Assessment of Bacterial contamination and associated risk factors in pork slaughtered and marketed in urban Tanzania

Cosmas Nonga[1*], Issa Zacharia[1], Ernatus Mkupasi[2] and Helena Ngowi[2]

[1] *Department of Food Science and Agro-processing, School of Engineering, P.O. Box 3005, Chuo Kikuu, Morogoro, Tanzania.*
[2]*Department of Veterinary Medicine and Public Health, College of Veterinary Medicine and Biomedical Science, P.O. Box 3021, Chuo Kikuu, Morogoro, Tanzania.*

Abstract
Introduction: In Tanzania, pork consumption is increasing and become popular in urban areas creating a good market for pigs raised in rural areas. However, little is known regarding the microbial safety of the marketed pork in the country. This study assessed the level of bacterial contamination and contributing factors in pork slaughtered and sold in Arusha, Dar es Salaam and Dodoma Tanzania through Total Viable count, Coliform count, *Escherichia coli* and *Staphylococcus aureus* count.
Methods: A cross-section study was conducted and a total of 90 pork samples were collected from pig slaughter facilities, pork centres and butcheries. Standard methods for microbial analysis in food products (ISO 7218:2007(E)) were used.
Results: It was revealed that all (100%) pork samples had bacteria contamination with an overall mean for total viable count of 5.93±1.50 log CFU/g, and coliform forming unit of 4.30±1.14 log CFU/g. Over 92.2% of the pork samples were contaminated by *E.coli* with a mean count of 3.12±1.33 and *S. aureus* was isolated in more than 84.4% with a mean count of 2.71±1.34 log CFU/g. The mean values were higher than the limit set by Tanzania Standard (TBS/AFDC 22 (5266) P3). In addition, 79.4% of the pork slaughter facilities and selling points surveyed had poor hygiene and lacked safety and quality control measures.
Conclusion: Thus, it may be deduced that the pork carcasses assessed were of poor microbiological quality posing a health risk to pork consumers. To minimize public health risks, food control authorities should ensure effective enforcement of policies and regulations in controlling pig slaughtering and pork marketing in the country. Also, education on hygienic practices for all stakeholders along the pork value chain should be provided.

Keywords: Bacteria contamination, pork, slaughter facilities, food safety, coliform bacteria

[*]*Corresponding author. Email:* cosmashezron1@gmail.com

Introduction

Pork is an excellent source of protein, essential fatty acids, minerals, and vitamins needed for human health, but it also supports the growth of numerous microorganisms (Bantawa *et al.,* 2018; Rortana *et al.,* 2021). Principally pork from a healthy pig contains no or very little number of microorganisms, however, contamination occurs during processing stages such as slaughtering, storage and transportation the source of contamination could be equipment, handlers and knives as well as other environmental sources like air and water (Soepranianondo and Wardhana, 2019; Uzoigwe *et al .,* 2021).

The pork and pork products contaminated with microorganisms pose a health risk to consumers as well as food losses due to spoilage (Pellissery *et al .,* 2020). Globally one-third of foods produced for human consumption is wasted each year (FAO, 2022). Food deterioration, which renders food unfit for consumption, is the main cause of this wastage. Since pork has a moderate pH and a high nutritional and moisture content compared to other food products, it is one of the most perishable foods. Microbiological proliferation is among the main causes of meat deterioration. Meat becomes unfit for human eating when its nutrients are broken down by microbial growth and autolysis, which causes the development of unpleasant smells and odours, the formation of slime, and discolouration (Pellissery *et al .,* 2020). The level of microbiological contamination is a good reflection of hygienic practices in pork handling (Bahir *et al.*, 2022).

About 1.9 million people worldwide die each year from food-borne infections, which are the primary cause of illness in underdeveloped nations (Abebe *et al.,* 2020). Significant underlying issues with food safety are shown by the high prevalence of diarrheal illnesses in many poor countries (WHO, 2022). Recently, food-borne illnesses which are associated with bacterial contamination in food including enterobacteria, *S.aureus* and *Salmonella* spp are becoming a major challenge in most African countries (Smith *et al*., 2022). Their presence and spread are associated with hygiene and handling practices.

The microbiological profile in pork products is the key criterion for determining the quality and safety of fresh produce (Kurpas *et al*., 2018). Ideally, pork should be considered wholesome when pathogens of concern are absent or if present should be at a low number depending on the toxin or metabolites produced (Bujang *et al.,* 2018). For raw meat products, safety and quality can be estimated by the use of indicator microorganisms, including Total Coliform Count (TCC), *S. aureus* and *E.coli* count (ECC) (Nurye and Demlie, 2021). Also, Total Viable Count provides an estimate of overall bacterial populations in a pork carcass or cuts. A higher TVC usually relates to poor quality and a reduced shelf life. The Tanzania Bureau of Standard have set the minimum limits for microbial load on pork carcasses to be 4log CFU/g for TVC, 2log CFU/g and completely absent for *S. aureus* and *E.coli* count (TBS, 2022).

In addition, in Tanzania, the Meat Industry Act (2006) provides guidance on meat standards and pork safety at the slaughter and butchery levels, through its emphasis on good premises and operators' hygiene. The absence of properly registered and properly regulated pig slaughter facilities as well as modern pork butchers which operate a hygienic environment brought a concern about the microbial quality and safety of pork marketed in Tanzania. Considering the increase in the consumption of pork in the country, proper hygiene and management for protecting public health and strengthening consumer confidence is required. Thus, all processing conditions are important factors which affect the microbiological quality of pork. To improve the safety of final pork products, more information on the on microbial status of pork and their risk factors is needed so as measures will be taken to improve processing environment and handling of pork. The current study was conducted to assess the level of bacterial contamination on pork carcasses from different pork slaughter places and pork centres and risk factors contributing to the bacterial contamination.

Material and methods

The study was conducted from February to June 2022 involving 3 major cities in Tanzania namely Dar-es-Salaam, Dodoma, and Arusha with a population of 5,383,728, 3,085,625, and 2,356,255 respectively (NBS, 2022). This was purposively selected as the major market for pigs from rural areas.

The study involved a cross-sectional design with the key informant and snowball sampling technique to collect pork samples from 34 slaughter facilities, 41 butcheries and 15 pork centres. The sample size was obtained based on the availability of the slaughter facilities, butcheries and pork centres. Therefore, a total of 90 pork samples were collected (30 samples per city).

Questionnaires and observational checklists were administered to participants from all 34 slaughter facilities, 41 butchers and 15 pork centres obtained through a key informant and snowball technique. One respondent from each facility, butcher or pork centre was interviewed. The information collected included level of education, accessibility to clean and safe water, health check-up of workers, storage facilities, premises condition, use of protective gear, hygienic status and presence of cold storage facilities. This was used for assessing risk factors contributing to microbial contamination.

Pork samples were collected directly from slaughter facilities, butcheries and pork centres. About 250 grams of pork samples were collected and packed in special sterile packets and labelled accordingly, kept in cool boxes with ice packs and subsequently transported to Sokoine University of Agriculture, College of Veterinary Medicine and Biomedical Sciences Microbiology Laboratory for Bacteriology. Microbiological analysis of pork samples involved the Total Viable Count (TVC), Total Coliform Count (TCC), identification and quantification of *Escherichia coli* and *Staphylococcus aureus* were done according to standard methods for food products (ISO 7218:2007(E)) and colonies were expressed in Log CFU/g. Data was analysed using Statistical Package for Social Sciences (SPSS) version 20.0 (IBM-SPSS Inc., Chicago, USA). All values for microbial parameters were presented as Mean ± SD. Statistical differences between pork samples were determined by one-way ANOVA and Duncan multiple comparison post hoc test; $P < 0.05$ was considered statistically significant.

Results

Risk factors and practices contributing to microbial contamination in pork

The results from the study revealed that majority of slaughter facilities, butcheries and pork centre workers have attained primary education. The facilities for pork sellers had poor adherence to regulation for the slaughter and pork selling points. It was found that facilities/premises layout for all the pork processing and selling environment was poor. Moreover, about (79.4%, n=34) slaughter facilities had poor premises condition followed by pork centres (73.3%, n=15) and majority do not have clean water systems, waste water drainage systems, toilets as well as waste decomposition pits and no zoning for different processes. Also the study revealed that the requirement of wearing personal protective equipment's (PPEs) such as white coat and gumboots were not followed by majority of the workers since about (73.3%, n=15) and (55.9%, n=34) of slaughter and pork centres workers respectively were not wearing them at working area and even some of them had dirty white coats. Furthermore, the study revealed that (62.3%, n=90) of all the assessed pork production and selling points did not have a cold storage facilities such as freezers for storing and pork were hanged on hooks or stored in plastic buckets (Table 1).

Table 1: Risk factors and practices contributing to microbial contamination in pork

Parameter	Category	Slaughter facilities 34	Butcher 41	Pork centres 15
Education	Informal	9(26.5)	5(12.2)	4(26.7)
	Primary	15(44.1)	18(43.9)	6(40)
	Secondary	10(29.4)	14(34.1)	5(33.3)
	Short training	0(0.0)	3(7.3)	0(0.0)
	College	0(0.0)	1(2.4)	0(0.0)
Facility/Premises	Good	7(20.6)	26(63.4)	4(26.7)
condition	Poor	27(79.4)	26(63.4)	11(73.3)
General hygiene	Clean	8(23.5)	28(68.3)	6(40)
	Dirty	26(76.5)	13(31.7)	9(60)
Wearing PPE	Wearing	15(44.1)	29(70.7)	4(26.7)
	Not wearing	19(55.9)	12(29.3)	11(73.3)
Health check-up of	After 3/6 month	6(17.6)	3(7.3)	0(0.0)
workers	Just once	20(58.8)	30(73.2)	6(40)
	No check up	8(23.5)	8(19.5)	9(60)
Cold facilities	Yes	0(0.0)	30(73.2)	4(26.7)
	No	34(100)	11(26.8)	11(73.3)

Total Viable Count in pork

All pork samples were contaminated with bacteria in which the highest mean values of TVC were on pork samples from selling centres with a mean count of 7.33±1.29 log CFU/g. Although there was no significant difference between contaminations load on pork from pork centres and slaughter facilities ($p > 0.05$). However the difference in microbial contamination between slaughter facilities, butcheries and pork centres were significant ($p < 0.05$). The maximum TVC observed was in the sample from retail shop with 8.84 log CFU/g and the minimum count was observed in pork sample from butchery with 3.00log CFU/g (Table 2).

Table 2: Mean values (log CFU/g) for Total Viable Count on pork from different pork slaughtering and selling points

Sampling source	N=90	Mean± SD	Min	Max
Slaughter facilities	34	5.58±1.35[a]	3.07	8.21
Butcheries	41	5.70±1.47[a]	3.00	7.93
Pork centres	15	7.33±1.29[b]	3.69	8.84

The values are expressed as mean± standard deviation (Log CFU/g). The mean values along the same column, with the same letters are not significantly different at P≤0.05. Standards: Total Viable Count (TVC) = ≤ 10^4/g (4log CFU/g)

Coliform count for pork samples

Table 3 shows the mean coliform of pork samples from the three (3) different vending sites. The coliform counts had similar trend with that obtained in Total Viable Count (Table 2). Pork samples from pork centres had the highest coliform counts 5.01±1.20 log CFU/g followed by pork sample from slaughter facilities by 4.95±0.94 log CFU/g while the lowest mean coliform count were observed in sample from butcher with 3.88±1.11 log CFU/g. Significant difference ($p < 0.05$) were observed between pork sample from pork centres and pork from slaughter facilities and butcher. Results indicated higher number of coliform compared to the minimum allowed limit by TBS.

Table 3: Mean values (log CFU/g) for Coliform Count on pork from different pork slaughtering and selling points

Sampling source	N=90	Mean± SD	Min	Max
Slaughter facilities	34	4.49±0.94[a]	2.85	6.34
Butchers	41	3.88±1.11[a]	2.10	5.85
Pork centres	15	5.01±1.20[c]	2.44	6.89

The values are expressed as mean± standard deviation (Log CFU/g). The mean values along the same column, with the same letters are not significantly different at P≤0.05. TBS limit: Coliform Count (CC) = ≤ 10^2/g (log CFU/g).

Occurrence of *Staphylococcus aureus* and *Escherichia coli* count in pork samples

The prevalence of *S. aureus* and *E. coli* in pork samples were 84.4% and 92.2% respectively (table 3). Pork samples from pork centres and slaughter facilities had higher mean contamination for *S. aureus* count by 3.15±1.58 Log CFU/g and 3.11±1.70 Log CFU/g respectively. Also for *E. coli* count the highest mean contamination were observed in samples from pork centres and butcheries by 3.53±1.37 Log CFU/g and 3.00±1.25 Log CFU/g respectively. However, there was no significant difference (p-value > 0.05 at 95% level) among the samples from slaughter facilities, butcher and pork centres. Moreover there was a significant difference (p-value< 0.05 at 95% level) for *S. aureus* between pork sample obtained in slaughter facilities and the samples from the other two pork selling site. For *E. coli a* significance difference (p-value< 0.05 at 95% level) was observed between sample from retail pork shops and the other three sources (table 4).

Table 4: Mean values (log CFU/g) for *S. aureus* and *E. coli* count in pork

Sampling source	N=90	*S. aureus* (Mean± SD)	*E. coli* (Mean± SD)
Slaughter facilities	34	3.11 ± 1.70^{b}	2.82 ± 1.32^{a}
Butcher	41	2.68 ± 1.01^{a}	3.00 ± 1.25^{a}
Pork centres	15	3.15 ± 1.58^{b}	3.53 ± 1.37^{b}

The values are expressed as mean± standard deviation. The mean values along the same column, with the same letters are not significantly different at P≤0.05. TBS limit: *S. aureus* and *E. Coli* count = absent (0).

DISCUSSION

The study assessed the microbiological quality of raw pork slaughtered and marketed in major cities in Tanzania and associated factors. The findings observed bacterial contamination in pork from all facilities although at different levels which was higher than the allowable level for pork intended for human consumption as per Tanzania Bureau of Standards and International standards, thus questioning its safety to the consumers. It was observed that all slaughtering activities were performed on small and dirty floor which predisposed pork to microbial contamination. The whole pork processing and selling environment was unhygienic which was correlated with poor premises and handling of pork.

Nearly all pork outlets lacked facilities for hand washing which includes soap and tape water for reducing cross contamination at working area. The poor hygiene of processing and selling environment exposes pork to microbial contamination (Kurpas *et al*., 2018; Uzoigwe *et al*., 2020). This were supported by the high values of microbial loads observed in pork samples. The findings demonstrate that all pork samples were contaminated with bacteria resulting to poor keeping quality for raw pork and predispose consumers to health risk.

It was observed that required hygienic practices in terms of personal hygiene, good manufacturing practices and food safety guidelines were not followed by workers in all pork production chain. This could be caused by lack of knowledge on food safety principles to some personnel who are involved in the slaughtering and selling pork. Similarly, a study by Cook *et al.* (2017) reported the impact of poor hygiene of slaughter and selling facilities on safety of pork marketed in Kenya. Furthermore, poor and unregulated vending areas which operate or sell pork at unhygienic environment reported to dominate the pork marketing system in Tanzania (Fasina *et al*., 2022).

Regarding microbial quality of pork, analysis revealed higher mean contamination for TVC in pork samples from slaughter facilities, butcheries as well as pork centres which exceeded the minimum allowed limit for microbial contamination on pork cuts and carcasses as per TBS/AFDC 22 (5266) P3 guidelines. This could be attributed by poor cleaning and sanitation which were observed in most of the facilities and premises. Also unhygienic handling of pork as well as dirty equipment used in pork preparation, and absence of cold storage facilities at all selling point as also reported by Uzoigwe *et al*. (2021). TBS specified the minimum limit for TVC in raw pork to be 4log CFU/g and the higher microbial load beyond the limit makes the pork susceptible to spoilage as well as posing a health risk to consumers (TBS, 2022).

Significance difference in TVC contamination were observed among the samples from slaughter areas and retail pork shops at ($P<0.05$). This could be due to differences in storage time, poor handling as well as lack of cold storage facilities. This provide an alert about safety along pork value chain. The observation are linked to the observed unhygienic processing and handling of pork in addition to absence of separation between clean and dirty operations in all slaughter places (Ray, 2019). Similar other studies reported that poor handling and storage of raw meat increases the chance of contamination and bacterial growth and hence accelerate meat spoilage (Kurpas *et al.,* 2018). Centralization of pig slaughtering and improving sanitary status of the facilities could help to reduce the microbial contamination.

This observation were similar to that of Eke and Elechi, (2021) in Nigeria reported higher bacteria contamination in meat from local retail meat vendors. The high TVC obtained from pork samples is an indication of ineffective and inadequate cleaning practice (Uzoigwe *et al*., 2021). Unhygienic practices in abattoirs and post-process handling are associated with potential health risk to consumers due to presence ofs pathogens in pork and contaminated equipment (Negash & Olga, 2021). In addition to that, pork were delivered by motorcycles to various retail pork outlets after animals is slaughtered this also could have increased chances of contamination. The contamination during pork sales at retail outlets can happen through contact with contaminated handling tools such as tables, logs, hooks, balances, and knives, buckets insects, air, staff, and even customers (Astill *et al.,* 2019; Samutela *et al.,* 2021)

Coliform organisms are indicator of fecal contamination and hence pathogenic organisms. The study revealed high mean coliform counts in pork from the slaughter areas and pork selling points exceeded the minimum allowed limit by TBS (TBS, 2022). Although the level of contamination varied depending on the nature and hygienic status of the slaughter place or selling point. This means the shelf life of the produced pork could be affected. Also the microbes can be infectious to consumers which can result into foodborne diseases and food loss as consequences of spoilage. According to TBS guidelines, the minimum allowed limit TCC in raw pork should be 2log CFU/g and higher level of coliform contamination are considered unfit for human consumption. Under tropical conditions with temperature which favour the growth of most bacteria, food of animal origin tends to deteriorate more rapidly and become an important vehicle for gastrointestinal infections, thereby endangering consumers' health (Akinro *et al*., 2009; Ercumen *et al*., 2020). Higher contamination incidences might be due to poor pork handling practices and lack of knowledge on sources of microbial contamination to pork (Haque *et al.,* (2022).

The study revealed high prevalence for *E.coli* contamination on pork samples where about (92.2%) of the analysed samples. As in case of coliforms count, the highest mean count was observed in samples from slaughter facilities and pork centres. *E. coli is* commonly used as an indicator, whereby its presence in food generally indicates faecal contamination and may also indicate the possible presence of disease-causing pathogens such as bacteria, viruses, and parasites (Puangseree *et al.,* 2021). This result implies that unhygienic pork handling in the slaughtering and pork selling points increases microbial contamination on pork sold in the area. A study along pork value chain in Uganda reported *E. coli* indicating possible cross-contamination (Kungu *et al*., 2017). In other hand, poorly organized production chain and poor sanitary operational procedures practiced by the slaughter personnel that include poor personnel hygiene were some of the factors which contributed to the high microbial load (Kanko *et al.,* 2023). The *E. coli* contamination on pork were against TBS regulatory guideline that prohibit the presence of harmful and spoilage bacteria in food intended for human use.

In this study, the presence of *S. aureus* was also tested as an important microbiocidal parameter. Over 84.4% of the pork samples were contaminated with *S. aureus*. Similar results were reported by Samutela *et al,* (2022) in Zambia. A previously study by Lee *et al.,* (2017) suggested that adherence to personal hygiene practices by food handlers is important in preventing cross contamination in food handling and preparation environment. In order to provide safe and high-quality products for consumers and consequently avoid microbial contamination and loss of products, effective sanitary handling of food meant for human consumption is of the extreme importance.

The occurrence of *S. aureus* isolated in some of pork samples was in consonance with a study done by Pal *et al.* (2016) who reported higher prevalence of *S. aureus* in raw pork. The reason for the high prevalence could be attributed by contamination from the environment and presence of the germs on parts of the handler body such as hands, nose, skin and clothing as a result of poor personnel hygiene at working environment. Other results by Barcenilla *et al.* (2022) have indicated that, poor hygiene and lack of refrigeration during storage enables outgrowth of spoilage and pathogenic microbes and thus a potential source of cross contamination during processing. A study by Nero *et al.* (2022) also reported higher counts for *S. aureus* in their tested samples was influenced by poor sanitary and hygienic practices among handlers. *S. aureus* and some of the coagulase-positive staphylococci species are human pathogens, causing a wide range of clinical signs, including foodborne illness, by its wide range of enterotoxins production (Amoako *et al*., 2020).

Therefore, in order to minimize the health risks associated with *S. aureus* contamination, processor and handlers need to take necessary actions to maintain food safety (Rugna *et al.,* 2021). Maintenance of the proper hygienic conditions during the processing of pork can reduce the prevalence of bacterial contamination in the pork (Nero *et al*. 2022). The bacteria from the contaminated pork may carry antimicrobial resistance traits and thus becoming harder to treat their related diseases as the antibiotic used to treat become less effective (Dadgostar, 2019).

Conclusion and recommendations

The study established higher microbial contamination levels ranging from 3.00 to 8.84 log CFU/g for TVC and 3.88 to 4.95±0.94 log CFU/g for coliform in pork marketed in the three cities exceeding the maximum recommended level in pork intended for human consumption.

E. coli and *S. aureus* has been isolated in most samples thus questioning the microbiological safety and quality of the pork marketed in the three cities. Poor hygienic conditions of slaughter facilities, butcheries, pork centres, personnel and absence of cold facilities observed to have contributed to the observed high level of microbial contamination

To guarantee pork safety for human consumption, responsible agencies/authorities should ensure adherence to and implementation of regulations, policies, rules, and procedures for sanitary slaughtering and handling of pork along the pork production chain. Furthermore, food control authorities should provide training to pork slaughters and sellers and conducting regular inspection and monitoring of pork slaughtering and selling points to safeguard the public health.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The author would like to appreciate and thank the German Federal Ministry of Education and Research (BMBF) for financial support of the research component through its Grant No. 01KA2025 as an add-on to the CYSTINET-Africa. Also, I would like to thank the Regional Administrative secretary of Dodoma, Arusha and Dar es Salaam for permission to collect data in their respective cities.

References

Abebe, E., Gugsa, G., & Ahmed, M. (2020). Review on major food-borne zoonotic bacterial pathogens. *Journal of tropical medicine*, *2020*.

Amoako, D. G., Somboro, A. M., Abia, A. L., Molechan, C., Perrett, K., Bester, L. A., & Essack, S. Y. (2020). Antibiotic resistance in Staphylococcus aureus from poultry and poultry products in uMgungundlovu District, South Africa, using the "Farm to Fork" approach. *Microbial Drug Resistance*, *26*(4), 402-411.

Astill, J., Dara, R. A., Campbell, M., Farber, J. M., Fraser, E. D., Sharif, S., & Yada, R. Y. (2019). Transparency in food supply chains: A review of enabling technology solutions. *Trends in Food Science & Technology*, *91*, 240-247.

Balali, G. I., Yar, D. D., Afua Dela, V. G., & Adjei-Kusi, P. (2020). Microbial contamination, an increasing threat to the consumption of fresh fruits and vegetables in today's world. *International Journal of Microbiology*, *2020*.

Bantawa, K., Rai, K., Subba Limbu, D., and Khanal, H. (2018). Food-borne bacterial pathogens in marketed raw pork of Dharan, eastern Nepal. *BMC research notes*, *11*(1), 1-5.

Barcenilla, C., Álvarez-Ordóñez, A., López, M., Alvseike, O., & Prieto, M. (2022). Microbiological Safety and Shelf-Life of Low-Salt Meat Products—A Review. *Foods*, *11*(15), 2331.

Bedane, T. D., Agga, G. E., & Gutema, F. D. (2022). Hygienic assessment of fish handling practices along production and supply chain and its public health implications in Central Oromia, Ethiopia. *Scientific reports*, *12*(1), 1-11.

Cook, E. A. J., de Glanville, W. A., Thomas, L. F., Kariuki, S., Bronsvoort, B. M. D. C., & Fèvre, E. M. (2017). Working conditions and public health risks in slaughterhouses in western Kenya. *BMC public health*, *17*(1), 1-12.

Dadgostar, P. (2019). Antimicrobial resistance: implications and costs. *Infection and drug resistance*, 3903-3910.

Eke, M. O., & Elechi, J. O. (2021). Food safety and quality evaluation of street vended meat pies sold in Lafia Metropolis, Nasarawa state, Nigeria. *Int. J. Sci. Res. in Biological Sciences*, *8*(1).

Ercumen, A., Prottas, C., Harris, A., Dioguardi, A., Dowd, G., & Guiteras, R. (2020). Poultry ownership associated with increased risk of child diarrhea: cross-sectional evidence from Uganda. *The American Journal of Tropical Medicine and Hygiene*, *102*(3), 526.

Fasina, F. O., Mtui-Malamsha, N., Nonga, H. E., Ranga, S., Sambu, R. M., Majaliwa, J., ... & Penrith, M. L. (2022). Semi-quantitative risk evaluation reveals drivers of African swine fever virus in smallholder pig farms and gaps in biosecurity, Tanzania.

Haque, M., Bosilevac, J. M., & Chaves, B. D. (2022). A review of Shiga-toxin producing Escherichia coli (STEC) contamination in the raw pork production chain. *International Journal of Food Microbiology*, 109832.

ISO methods for microbiology of food and feed stuffs [https://www.iso.org/standard/36534.html]. Site visited on 20/06/2021.

Kanko, T., Seid, M., & Alemu, M. (2023). Evaluation of bacteriological profile of meat contact surfaces, handling practices of raw meat and its associated factors in butcher shops of Arba Minch town, southern Ethiopia-A facility based cross sectional study. *International Journal of Food Contamination*, *10*(1), 1-13.

Kothari, Chakravanti, R (2004.). *Research methodology: Methods and techniques*. New Age International.

Kungu, J. M., Dione, M., Roesel, K., Ejobi, F., Ocaido, M., & Grace, D. (2017). Assessment of hygiene practices of pork retail outlets in Kampala district, Uganda. *International Food Research Journal*, *24*(4), 1368.

Kurpas, M., Wieczorek, K., & Osek, J. (2018). Ready-to-eat meat products as a source of. *Journal of veterinary research*, 62(1), 49-55.

Lee, H. K., Abdul Halim, H., Thong, K. L., & Chai, L. C. (2017). Assessment of food safety knowledge, attitude, self-reported practices, and microbiological hand hygiene of food handlers. *International journal of environmental research and public health*, *14*(1), 55.

Negash, A., & Olga, K. (2021). Goat carcass microbial investigation in Modjo Export Abattoirs, Ethiopia. *Journal of Microbiology and Antimicrobials*, *13*(2), 37-49.

Pellissery, A. J., Vinayamohan, P. G., Amalaradjou, M. A. R., & Venkitanarayanan, K. (2020). Spoilage bacteria and meat quality. In *Meat quality analysis* (pp. 307-334). Academic Press.

Puangseree, J., Jeamsripong, S., Prathan, R., Pungpian, C., & Chuanchuen, R. (2021). Resistance to widely-used disinfectants and heavy metals and cross resistance to antibiotics in Escherichia coli isolated from pigs, pork and pig carcass. *Food Control*, *124*, 107892.

Ray, B. (2019). Foods and microorganisms of concern. In *Food Biopreservatives of Microbial Origin* (pp. 25-55). CRC Press.

Rortana, C., Nguyen-Viet, H., Tum, S., Unger, F., Boqvist, S., Dang-Xuan, S and Lindahl, J. F. (2021). Prevalence of Salmonella spp. and Staphylococcus aureus in chicken pork and pork from Cambodian Markets. *Pathogens*, *10*(5), 556.

Rugna, G., Carra, E., Bergamini, F., Franzini, G., Faccini, S., Gattuso, Aand Giacometti, F. (2021). Distribution, virulence, genotypic characteristics and antibiotic resistance of Listeria monocytogenes isolated over one-year monitoring from two pig slaughterhouses and processing plants and their fresh hams. *International Journal of Food Microbiology*, *336*, 108912.

Samutela, M. T., Kwenda, G., Simulundu, E., Nkhoma, P., Higashi, H., Frey, A.,& Hang'ombe, B. M. (2021). Pigs as a potential source of emerging livestock-associated Staphylococcus aureus in Africa: a systematic review. *International Journal of Infectious Diseases*, *109*, 38-49.

Samutela, M. T., Phiri, B. S. J., Simulundu, E., Kwenda, G., Moonga, L., Bwalya, E. C., ... & Hang'ombe, B. M. (2022). Antimicrobial Susceptibility Profiles and Molecular Characterisation of Staphylococcus aureus from Pigs and Workers at Farms and Abattoirs in Zambia. *Antibiotics*, *11*(7), 844.

Silhavy, T. J. (2016). Classic spotlight: Gram-negative bacteria have two membranes. *Journal of bacteriology*, *198*(2), 201-201.

Smith, M. A., Olimpo, J. T., Santillan, K. A., & McLaughlin, J. S. (2022). Addressing Foodborne Illness in Côte d'Ivoire: Connecting the Classroom to the Community through a Nonmajors Course-Based Undergraduate Research Experience. *Journal of Microbiology & Biology Education*, *23*(1), e00212-21.

Soepranianondo, K., and Wardhana, D. K. (2019). Analysis of bacterial contamination and antibiotic residue of beef pork from city slaughterhouses in East Java Province, Indonesia. *Veterinary world*, *12*(2), 243.

Tanzania population by Nation Bureau of Statistics [https://sensa.nbs.go.tz/]. Site visited on 12/11/2022.

Tanzania Standard for pork and pork carcasses {http://168.101.26.37/notific_otros_miembros/tza133_t.pdf}.Accessed on 13/10/2022.

Uzoigwe, N. E., Nwufo, C. R., Nwankwo, C. S., Ibe, S. N., Amadi, C. O., & Udujih, O. G. (2021). Assessment of bacterial contamination of beef in slaughterhouses in Owerri zone, Imo state, Nigeria. *Scientific African*, *12*, e00769.

WHO. Food safety and food borne illness. Factsheets of the Programmes and Projects of WHO.2022.[https://www.who.int/news-room/fact-sheets/detail/food-safety] Accessed on 13/10/2022