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Heavy Metal	Food type			
	Pap	Chicken	Pork	Morocho/salad
Copper	0.001	0.0003	0.0001	0.002
Iron	0.023	0.007	0.007	0.016
Zinc	0.019	0.005	0.005	0.013
Arsenic	0.011	0.009	0.002	0.016
Cadmium	<0.0000	0.0003	<0.0000	0.0001
Chromium	0.001	0.0003	0.0003	0.0007
Lead	0.006	0.002	0.002	0.004

According to USEPA, a one in a million chance of contracting cancer over a 70-year lifetime period ( $ICLR=10^{-6}$ ) is considered acceptable, while  $ICLR$  of/or greater than  $10^{-3}$  (one in a thousand) is said to be serious and is a cause for remediation (Li *et al.*, 2013). In this study, cancer risk was computed as  $2.44 \times 10^{-2}$  for highest and  $3.17 \times 10^{-3}$  for lowest risk for morocho/salad and pork, respectively. Cumulatively, all  $ICLR$ s were found to be equal to or greater than what is considered to be an increased risk of cancer ( $10^{-3}$ ). The chronic exposure to low concentrations of heavy metals such as Pb, As and Cd has the potential to result in many forms of cancers, while these metals also pose the risk of other toxic effects (Bhattacharjee *et al.*, 2016; Flora and Agrawal, 2017). The toxicity of chromium is dependent on its chemical composition. The health effects of chromium exposure can include, but are not limited to, respiratory problems, lung cancer, and skin effects (Teklay, 2016).

**Table 5.10 ICLR for adults in MMM through the consumption of street-vended foods**

Heavy Metal	Food type			
	Pap	Chicken	Pork	Morocho/salad
Arsenic	$1.65 \times 10^{-2}$	$1.35 \times 10^{-2}$	$3.00 \times 10^{-3}$	$2.40 \times 10^{-2}$
Cadmium	0	$1.14 \times 10^{-4}$	0	$3.80 \times 10^{-5}$
Chromium	$5.00 \times 10^{-5}$	$1.50 \times 10^{-4}$	$1.50 \times 10^{-4}$	$3.50 \times 10^{-4}$
Lead	$5.10 \times 10^{-5}$	$1.70 \times 10^{-5}$	$1.70 \times 10^{-5}$	$3.4 \times 10^{-5}$
$\Sigma$ ICLR	$1.66 \times 10^{-2}$	$1.38 \times 10^{-2}$	$3.17 \times 10^{-3}$	$2.44 \times 10^{-2}$

**Table 5.11 The hazard quotient of heavy metal for oral ingestion in adults**

Heavy Metal	Food type			
	Pap	Chicken	Pork	Morocho/salad
Copper	0.025	0.008	0.003	0.05
Iron	3.286	1	1	2.286
Zinc	0.063	0.017	0.017	0.043
Arsenic	36.67	30	6.67	53
Cadmium	<0.001	0.6	<0.001	0.2
Chromium	0.33	1	1	2.33
Lead	1.71	0.57	0.57	1.14
$HI = \Sigma HQ$	42.085	33.195	9.261	59.019

Aina *et al.* (2023) describe the hazard quotient as “a proportion of the probable exposure to an element or chemical at such a level with no expected negative impacts when the quotient is less than 1, but an indication of potential health risks resulting from exposure, when it is greater than 1”. The hazard quotients (HQs) were calculated to determine the non-cancer risk for all metals evaluated in this study. The results are presented in Table 5.11. The HQs

in decreasing order are: As, Fe, Pb, Cr, Zn, Cu and Cd for pap; As, Fe, Cr, Cd, Pb, Zn and Cu for chicken; As, Fe, Cr, Pb, Zn, Cu and Cd for pork; and As, Cr, Fe, Pb, Cd, Cu, and Zn for moroho/salad. The HQs were less than 1 in 86% (6 out of 7) of the heavy metals in chicken and pork, with As being the only heavy metal with an HQ >1. Similar observations were reported by Bamuwanye *et al.* (2015).

The hazard index (HI) for individual food types was calculated and the results in descending order were as follows:  $HI_{\text{moroho/salad}}$  50.019,  $HI_{\text{pap}}$  42.085,  $HI_{\text{chicken}}$  33.195 and  $HI_{\text{pork}}$  9.261. The HI of all the sampled food types as per their daily ingestion rate indicated that consumers were at a significant non-carcinogenic health risk. The results in Table 5.11 show that As THQs were the major contributors to the very high HI in all the food types. Contrary to the findings of this study, Kaushik *et al.* (2023) reported a target hazard quotient and hazard index of <1 for all analysed metals, which was indicative of health risks being lower.

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## CHAPTER 6

### CONCLUSIONS, LIMITATIONS, AND RECOMMENDATIONS

#### 6.1 CONCLUSIONS

This chapter reflects on the key findings and the overall conclusions related to the study objectives. The primary aim of this study was to evaluate the safety of street-vended foods and the nutritional knowledge of vendors operating in the Mangaung Metro Municipality in the Free State province. Pursuant to this aim, the following objectives that related to street food vending in the study area were to:

- Assess street food vendors' nutrition knowledge and practices;
- Assess the microbial contamination of street-vended foods;
- Explore the extent of the threat of *Staphylococcus aureus* contamination in RTE foods;
- Identify the extent of heavy metals present in street-vended foods using Inductively Coupled Plasma Atomic Absorption Spectroscopy (ICP-AAS); and
- Determine/calculate the cancer and non-cancer risk posed by heavy metals in both adults and children who may consume street-vended foods in the study area.

In Chapter 2, the assessment of street food vendor nutrition knowledge and practices revealed that, although these vendors in the study are had some good knowledge and positive attitudes towards food nutrition, the food types and food portions they served might compromise consumers' health. Key findings were that the vended foods were often energy-dense, high in salt, high in saturated fats, and comprised mostly unbalanced meals in terms of nutritional value. Therefore, in consideration of the many benefits of street-vended foods such as cultural preservation and combating food insecurity, changing the food menu or food preparation methods could threaten the profitability and in turn the livelihoods of the street food vendors.

For nutritional assessment, the microbiological quality of the vended foods was also assessed. The findings of this investigation were presented in Chapter 3. These findings revealed valuable insights into the microbiological quality and safety of ready-to-eat street-vended foods sampled from various locations within the Mangaung Metro Municipality. The presence of bacterial isolates such as *Staphylococcus* spp., *E. coli*, and *Pseudomonas* spp. highlighted significant public health concerns related to street food handling and vendors' hygiene practices.

Findings related to the total viable counts (TVC) of the analysed food samples indicated that a substantial proportion of the street-vended foods did not meet acceptable microbial safety standards and could pose a risk to consumers. Additionally, the detection of *E. coli* in 100% of the samples, with contamination levels exceeding permissible limits in RTE foods, further underscores the potential for faecal-oral contamination and the need for improved food preparation and handling by street food vendors. Moreover, the high prevalence of *Pseudomonas* spp. (78.5%) in the food samples posed risks associated with biofilm formation on cooking surfaces, which may potentially contribute to persistent cross contamination now and in the future.

In light of the above conclusions, the study highlights the need for stricter enforcement of hygiene regulations, mandated training of food handlers, and regular microbial assessments of street-vended foods. Extensive and ongoing research that releases statistical analyses should be conducted to provide in-depth insights into the significance of contamination patterns across different food types and locations. Such data are currently lacking in the research setting. Addressing these concerns is crucial to safeguard public health and ensure the safety of RTE foods across the board.

Expanding on the microbiological findings, Chapter 4 enhanced understanding of *S. aureus* genotypes found in the street-vended foods. These findings should aid in the development and management of effective strategies to better control street food vending and

consequently protect public health. Multidrug-resistant (MDR) strains were detected in high frequency in this study in over 50% of isolates. In addition, critical virulence determinants, including genes encoding hemolysins, leukocidins, and biofilm-associated MSCRAMMs, were detected. The prevalence of these strains is suggestive of the public health threat posed by these pathogens that abounded in the informal food markets under study. Furthermore, the importance of the One Health approach in understanding the ecology and transmission of *S. aureus* is highlighted by the genomic characterization that revealed the close phylogenetic relatedness between food-derived isolates and those of human and animal origins. Antimicrobial resistance genes, such as *tet (38)*, *mepA*, *lmrS*, and *norA* that are often associated with efflux-related resistance mechanisms, were found in the foods that were analysed. These genes are indicative of the adaptive potential of this pathogen under antimicrobial pressure. According to the findings, RTE are implicated not only as potential reservoirs facilitating the horizontal transfer of resistance determinants, but also as vehicles for direct human exposure to virulent and drug-resistant *S. aureus* strains. As a result, remedial interventions such as intensified surveillance, stricter enforcement of food safety regulations, and comprehensive risk communication strategies are urgent. These interventions should be contextually tailored to specific settings in order to ensure efficiency and implementation.

To conclude the food safety assessments of the street foods vended in the MMM, analyses of heavy metal contamination were conducted. All the food samples that were analysed tested positive for the range of heavy metals tested. Although some of the metals are essential trace elements, exposure to them in concentrations exceeding safety standards can be detrimental to the health of consumers. The estimated daily intake obtained for all the heavy metals that were tested was below the recommended limits, thereby indicating no real risk to public health. However, the results of the incremental lifetime cancer risk indicated the necessity for attention and remediation. Moreover, the hazard index of the various food types was disconcertingly high ( $HI > 1$ ). This result implies that habitual consumers are at risk of contracting non-carcinogenic health conditions. The high HI

observed could be attributed to various reasons, such as low RfD and the cumulative exposure to multiple heavy metals. With the aim of addressing the health and safety issues posed by the consumption of street-vended foods, food safety education and regulatory support need to be prioritised. This will help reinforce and cement the value of street food vending to ensure food security and address the socio-economic challenges associated with street food vending in a safe and appropriate manner.

## 6.2 STUDY LIMITATIONS

Due to limited funds available for the study, genetic data for other isolates could not be extracted, therefore *S. aureus* was prioritized. Moreover, the study focused on the MMM in particular, which limited its scope and thus prevent the findings from being generalised.

## 6.3 RECOMMENDATIONS

In line with the findings of the study, the following recommendations are offered:

- Targeted training programs that improve the knowledge of vendors, inform them of nutrition requirements, advise them of the quality of the value-for-money food that they sell, and equip them with health-related knowledge should be implemented.
- Mandatory hygiene and food safety training should be implemented for food vendors to promote and enhance safe food handling practices.
- Collaborative efforts towards providing access to clean water, waste disposal facilities, and adequate vending stalls should be explored to help curb the spread of foodborne pathogens.
- One Health efforts should be implemented for interdisciplinary collaboration among the food safety, human health, and animal health sectors to address the transmission of pathways of resistant organisms.
- Future studies should expand the scope of this study by conducting similar investigations into street food vending in other human-congested areas in South Africa.