Urmia University

Food Safety and Packaging

2026, 2 (1): 25-32

Journal Homepage: fsp.urmia.ac.ir

FOOD Safety and Packaging

Research Article

Microbiological quality and heavy metal contamination of ready-to-eat street-vended food wrapped in ink-printed papers in Dar-Es Salaam, Tanzania

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Abstract

Street-vended food is perceived as a significant public health risk. Foods wrapped in ink-printed papers have been associated with several health issues, including cancer, neurological disorders, reproductive complications, and kidney and liver damages. This study examined heavy metal contamination and the microbiological quality of ready-to-eat foods (chapatti) wrapped in ink-printed paper in Dar es Salaam, Tanzania. Samples were collected and analyzed for lead (Pb), chromium (Cr), and cadmium (Cd) using microwave plasma atomic emission spectrometry. Microbiological assessment was conducted to determine the total plate count (TPC), and the presence of *Staphylococcus aureus* and *Escherichia coli*. Data analysis was performed using Python-based analytical tools to calculate mean values and assess statistical significance. The results indicated that the mean concentrations of Pb, Cr, and Cd were all significantly higher ($p < 0.05$) in the wrapped samples than in the unwrapped controls, with mean levels varying from 0.05–0.06 mg/kg, 0.07 mg/kg, and 0.06–0.07 mg/kg, respectively. Likewise, wrapped samples had significant microbial contamination, with mean TPC and *S. aureus* levels of 2.64 ± 0.17 $\log_{10}$ CFU/g and 1.67 ± 0.16 $\log_{10}$ CFU/g, respectively, while these bacteria were not present in the control samples. None of the samples tested positive for *E. coli.* Although measured heavy metal concentrations remain below current regulatory thresholds, the marked increase in contamination originating from ink-printed papers constitutes a potential public health concern. The results clearly demonstrate that the wrapping material is the principal source of contamination. Therefore, it is advisable that regulatory bodies, including the Tanzania Bureau of Standards and local government health officials, prohibit the use of printed materials, such as newspapers, for food contact.

Keywords: Heavy metals, Ink-printed paper, Microbiological Quality, Migration, Street-vended Food.

Introduction

Food security encompasses not only the physical and economic accessibility of food but also its safety and nutritional value. In recent years, food accessibility has been influenced by several factors, including population growth, globalization, and changes in consumer behavior. For many years, people have preferred ready-to-eat foods over preparing meals at home. Ready-to-eat foods are frequently inadequately packaged, often utilizing ink-printed materials such as newspapers, magazines, examination papers, and calendars, which are more cost-effective than alternative packaging methods (Jadhav et al., 2020). These materials frequently include hazardous chemicals from inks and dyes that

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https://doi.org/10.30466/fsp.2026.56788.1026
Received: 27 November 2025 **Accepted**: 27 January 2026 **Available online**: 15 February 2026

may leach into food, particularly when greasy (Jadhav et al., 2020). Dzikunoo et al. (2021) found that eating wrapped food has gained popularity in most African countries. However, the safety of food wrapped in printed ink paper remains a significant concern. This is because most food handlers do not observe hygienic practices along their processing line, hence providing a chance for microbiological contamination, some of which are pathogenic. The porous, cellulose-based surface of paper can harbor and transfer enteric pathogens such as *Escherichia coli, Salmonella spp.* and *Staphylococcus aureus*. When wrapped around food, these microorganisms can be transferred onto the product. Therefore, the practice of wrapping ready-to-eat (RTE) foods in ink-printed paper creates a unique and critical point of contamination in the food chain, where persistent chemical toxins and proliferating biological agents converge. This poses a significant under-quantified threat to public health, particularly in urban populations with high street-vended food consumption rates.

Likewise, the use of ink-printed papers leads to contamination of wrapped foods by heavy metals such as chromium, lead, and cadmium due to the high chance of dissociation of ink components into the food. When contaminated food is consumed by humans, microbes and heavy metals enter the human digestive system and eventually reach various metabolic systems, including the liver and kidneys (Munir et al., 2021). These heavy metals are of paramount concern in food safety because of their non-biodegradable nature, bio-accumulative potential, and profound toxicity, even at low levels of chronic exposure. When used to wrap foods, especially those that are greasy, acidic, or hot, the ink components, including these metals, can migrate into the food matrix (Dzikunoo et al., 2021). Upon ingestion, heavy metals bypass the body's natural detoxification pathways and accumulate in vital organs, such as the liver, kidneys, and bones. Chronic exposure is linked to a spectrum of debilitating health outcomes, including neurodevelopmental disorders in children, renal dysfunction, cardiovascular diseases, and various cancers (Munir et al., 2021). Thus, the use of ink-printed paper represents a direct and preventable route for heavy metal entry into the human food chain.

The four basic components used to prepare printing inks are pigments, resins, additives, and solvents (Gupta et al., 2020). Pigments provide color and influence the physical and chemical properties of ink. Resins control the viscosity of the ink and act as binding agents by helping the ink adhere to the printing surface, such as paper. Additives function as anti-foaming agents, enhance adhesion, and improve wetting by enabling the ink to spread evenly across the surface. Solvents, which enable ink transfer from printing equipment to the substrate, such as paper, improve print quality, enhance substrate compatibility, and dissolve ink components. However, ink pigments contain heavy metals, such as cadmium, mercury, lead, and chromium (Jadhav et al., 2020). These toxic metals may endanger human health when consumed, as they are associated with cancer, reproductive disorders, kidney damage, and neurological problems (Munir et al., 2021). Wrapping fried food in printed papers is an unhealthy practice, and its consumption may pose health problems even though the food has been cooked hygienically, since the paper used for wrapping, serving, and carrying may have microorganisms before wrapping the food (Hassan et al., 2025). The printed papers are produced under strict aseptic conditions, but unhygienic handling at shops, by street newspaper sellers, readers, supermarkets, transport and distribution, dirty stores, and other retail outlets may be liable to microbial contamination (Hassan et al., 2025).

Despite the potential health risks posed to humans, few studies have assessed the levels of heavy metal contamination and microbiological quality of ready-to-eat foods wrapped in printed paper. This study assessed the levels of heavy metal contamination (lead, Pb; cadmium, Cd; and chromium, Cr) and the microbiological quality of ready-to-eat fried food wrapped in ink-printed paper vended in Dar es Salaam. The information generated from this study adds to the body of knowledge and alerts national and international regulatory bodies to set policies, acts, and regulations to control the use of ink-printed papers in wrapping foods to protect the health of consumers or the public in general.

Materials and Methods

Materials and reagents

The primary instruments used included a microwave plasma atomic emission spectrometer (MP-AES; model 4210, Agilent Technologies Inc., Santa Clara, CA, USA) for heavy metal detection and an advanced microwave digestion system (Milestone ETHOS Easy, Milestone Srl, Sorisole, BG, Italy) for sample preparation, supported by an analytical balance (Mettler Toledo). All chemicals, including nitric acid (69-70%) and hydrogen peroxide (30%) (SIL Chemical Limited), were of analytical grade. Microbiological analysis utilized culture media, such as plate count agar (PCA), peptone water, mannitol salt agar, and MacConkey agar (HiMedia Laboratories Pvt. Ltd.).

Description of study area

The study was conducted in the districts of Kinondoni, Temeke, and Kigamboni in the Dar es Salaam Region, Tanzania. The Region is located on the east coast of Tanzania, lies between latitudes 6.45 °S and 7.25 °S and longitudes 39 °E and 39.55 °E (**Figure 1**). It borders the Indian Ocean to the east and the Coast (Pwani) region on the other side. According to the 2022 Tanzania census, the total population of the region is above five million people.

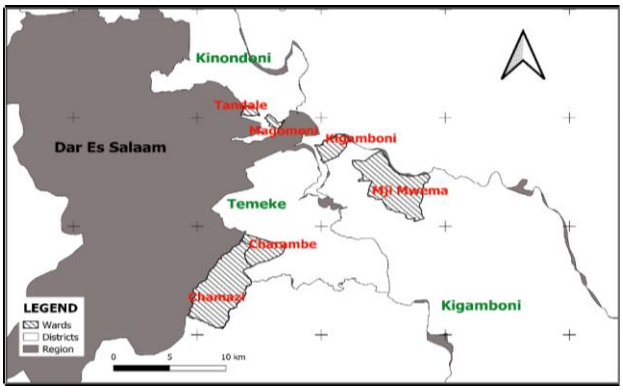

Figure 1. Map of Dar Es Salaam Region showing study sites (Kinondoni, Temeke and Kigamboni Districts).

Research design and data collection

This study adopted a descriptive cross-sectional design. Samples were collected using a purposive sampling method. All collected samples were transported to the Tanzania Bureau of Standards Laboratories, where they underwent standardized analytical procedures to determine the concentrations of heavy metals and assess microbiological quality.

Sample collection and preparation

A purposive sampling strategy was utilized to gather sixty (60) "Chapatti" samples from street vendors who exclusively employed ink-printed paper as wrapping material (in both Swahili and English). The sample size was determined to facilitate a comparative case-control analysis. The cohort consisted of a test group (n = 30), which remained in the original ink-printed wrappers to mimic consumer exposure, and a control group (n = 30), which was aseptically placed into sterile stomacher bags immediately after purchase to establish a contamination baseline. Sampling was conducted in a stratified manner across three districts (Kinondoni, Temeke and Kigamboni) to ensure geographical representation, with 20 samples obtained from each district. This design (30/30 stratified across three sites) establishes a strong basis for statistical comparison and improves the generalizability of the findings. All samples were promptly stored in insulated cool boxes and subsequently kept at refrigeration temperatures (5±3 °C) until laboratory analysis to ensure their integrity.

Determination of levels of heavy metals

The samples (0.5 g) were placed in a digestion tube, followed by the addition of concentrated digestion solution (6 mL of nitric acid and 1 mL of hydrogen peroxide). The mixture was digested at 200 °C using an advanced microwave digester (Milestone ETHOS Easy) following the pre-installed program in accordance with the US EPA method 3015. Upon completion of digestion, the mixture was transferred into a 50 mL Teflon tube, followed by the addition of distilled water to the mark and thorough mixing using a vortex mixer. Five mL was extracted from a 50 mL mixture and transferred into a 10 mL Teflon tube, followed by dilution with 5 mL of distilled water and mixing using a vortex mixer. Finally, the analytical sample was placed in auto sampler rack for analysis by the microwave plasma atomic emission spectrometer (MP-AES; Agilent Technologies model 4210). The blank sample was

prepared using the same steps. The machine was calibrated by using calibration standard solutions prepared at concentrations of 5, 10, 25, 50, 75, and 100 ppb. Each element was analyzed at its specific wavelength, and the final results obtained from the machine were quantified in mg/kg.

Determination of microbiological quality

Twenty-five grams of the "chapati" sample were cut into small pieces to facilitate the easy dissolution of microbes contained in the "chapati" sample into the buffered peptone solution. A volume of 225 mL of buffered peptone water was used to dissolve twenty-five grams of the sample in a Stomacher homogenizer (Model 22, TUL Instruments, Barcelona, Spain) under sterile conditions until a homogenous mixture with a concentration of 10^{-1} was achieved. The homogenizer's working surface was first sterilized using 70% ethanol, and then it was rinsed with sterile distilled water. Then, 10-fold serial dilutions of the sample with sterile buffer were aseptically performed. From each dilution, 1 ml was taken in duplicate and inoculated onto a sterile petri dish containing 15-20 ml of PCA for total plate count (TPC), MacConkey agar (MCA) for *E. coli*, and Baird Parker agar (BPA) and mannitol salt agar (MSA) for *S. aureus*, and incubated at 37 °C for 24 h for TPC and *E. coli* and 48 h for *S. aureus.* Finally, colonies were enumerated, and the average colony units were reported as colony-forming units ($\log_{10}$ CFU/g).

Statistical analysis

Data on heavy metal and microbial contamination were analyzed using the Python programming language (Python Software Foundation, version 3.13.0). For both types of contamination, independent samples t-tests were employed to compare mean concentration levels between wrapped and unwrapped Chapati samples across all selected districts. Statistical significance was defined as a p-value of less than 0.05, corresponding to a 95% confidence level.

Results and Discussion

Heavy metal concentration in Chapati in Dar Es Salaam

An independent sample t-test was employed to evaluate the heavy metal concentrations in Chapati served in Dar es Salaam as a ready-to-eat food. **Table 1** presents the average heavy metal concentrations in the samples. The mean concentration levels (mg/kg) for the wrapped samples of Pb, Cr, and Cd at Kinondoni were 0.05 ± 0.01, 0.07 ± 0.01, and 0.07 ± 0.01, respectively; at Temeke were 0.06 ± 0.01, 0.07 ± 0.01, and 0.07 ± 0.01, respectively; and at Kigamboni were 0.06 ± 0.01, 0.07 ± 0.01, and 0.06 ± 0.01, respectively. The results showed that the wrapped Chapati samples had higher mean concentrations of Pb, Cr, and Cd than the unwrapped samples across all the selected districts. **Table 1** demonstrates significant differences in the concentrations of heavy metals (Pb, Cr, and Cd) between wrapped and unwrapped food samples at all studied locations, as evidenced by a p-value of less than 0.05. These results suggest that wrapped foods contain higher concentrations of heavy metals than unwrapped foods, indicating potential contamination or migration of toxic metals from ink-printed paper used for wrapping food. This trend was consistent across all three districts.

The inked papers contain pigments comprising various heavy metals such as Pb, Cr, and Cd (Muncke, 2011; Bhunia et al., 2013; Jadhav et al., 2020). Factors such as the hotness and oiliness of the wrapped food increase the migration of heavy metals and other contaminants from packaging materials into food. Furthermore, the oils in ready-to-eat food act as solvents for lipophilic contaminants, accelerating the diffusion of heavy metals from paper inks (Begley et al., 2005; Mortazavighahi & Rashidi, 2024). Rahman and Singh (2019) also reported that heavy metals may be introduced through the use of cheap and recycled inked papers, which are widely available and commonly used by street vendors, resulting in high levels of heavy metal contamination in the wrapped food. According to WHO (2015), mean concentrations for all the heavy metals in this study fall within the allowable or acceptable regulatory limits for food products. Despite being within acceptable limits, heavy metals in wrapped foods still pose health risks, as they are highly toxic to the human body (Ahmad & Bashir, 2021; Muendo et al., 2024).

Table 1. Heavy metal contamination in wrapped and unwrapped food in Dar Es Salaam districts

Area	Wrapped (mg/kg)			Unwrapped (mg/kg)			P-Value (Pb)	P-value (Cr)	P-value (Cd)
	Pb	Cr	Cd	Pb	Cr	Cd			
Kinondoni	0.05 ± 0.01	0.07 ± 0.01	0.07 ± 0.01	0.03 ± 0.02	0.04 ± 0.01	0.05 ± 0.01	0.003	0.000	0.006
Temeke	0.06 ± 0.01	0.07 ± 0.01	0.07 ± 0.01	0.03 ± 0.01	0.04 ± 0.02	0.03 ± 0.02	0.000	0.000	0.000
Kigamboni	0.06 ± 0.01	0.07 ± 0.01	0.06 ± 0.01	0.03 ± 0.02	0.03 ± 0.01	0.02 ± 0.01	0.002	0.000	0.000

On the other hand, the results show a notable amount of mean concentration of heavy metals in all selected districts of the study sites for the unwrapped samples, but in a lower amount as compared to wrapped ones (**Table 1**). Thus, mean concentration levels for unwrapped samples (mg/kg) of Pb, Cr and Cd at Kinondoni were 0.03 ± 0.02, 0.04 ± 0.01, and 0.05 ± 0.01, respectively; at Temeke were 0.03 ± 0.01, 0.04 ± 0.02 and 0.03 ± 0.02, respectively; and Kigamboni were 0.03 ± 0.02, 0.03 ± 0.01 and 0.02 ± 0.01 respectively. The detected amounts may originate from the raw materials used to prepare the Chapati samples, such as wheat flour, cooking oil, and water. This can be proved by various studies as follows: The use of fertilizers, particularly phosphate-based fertilizers (Diammonium phosphate (DAP) and single super phosphate (SSP)) can contribute to Pb and Cr accumulation in wheat grain (Siddque et al., 2023). According to Oniya et al. (2018), the milling process can cause Pb, Cr, and Cd contamination to the wheat flour, especially if the milling equipment is made from steel alloys or coated with chromium. Not only that, the study by Li et al. (2020) reported that soil contamination due to industrial activities can significantly contribute to Pb and Cd levels in wheat grain and eventually to the products made from it. Generally, wrapped food samples show higher concentrations of heavy metals compared to unwrapped ones, confirming that these toxic metals migrate from printed paper to the wrapped food. Additionally, there was a statistically significant difference ($p < 0.05$) between the wrapped and unwrapped samples, although the detected values remained below the acceptable limits set by both local and international standards.

Microbiological contamination in wrapped and unwrapped Chapati in Dar Es Salaam

To assess the microbiological quality of the samples, TPC, *S. aureus*, and *E. coli* were analyzed in both wrapped and unwrapped samples across all selected districts in Dar es Salaam. The mean microbial loads for wrapped fried food samples are presented in **Figures 2, 3,** and **4**. The TPC and *S. aureus* levels were 2.65 ± 0.14 and 1.68 ± 0.09 $\log_{10}$ CFU/g in Kinondoni, 2.66 ± 0.16 and 1.68 ± 0.24 $\log_{10}$ CFU/g in Temeke, and 2.59 ± 0.20 and 1.65 ± 0.12 $\log_{10}$ CFU/g in Kigamboni, respectively. In contrast, TPC and *S. aureus* were undetected in all unwrapped samples. These results demonstrate that wrapped samples exhibited significantly higher microbial contamination across all study sites. Moreover, the results showed significant differences in microbial contamination between wrapped and unwrapped samples across all districts ($p<0.05$). In this case, the microbiological contamination may likely come from wrapping materials (printed paper) due to its handling practices at warehouses, shops, transportation, market, and the person who wraps the food. Thus, poor handling practices of the printed paper by the street food vendors might be a strong reason for the microbial contamination of the wrapped street food (Chapati).

The presence of *S. aureus* in wrapped food might come from various sources such as hands, skin, and nasal cavities of the street food vendors in the study

sites, or any handler through the whole distribution chain. Therefore, the act of wrapping provides opportunities for contamination by the street food vendors (Letuka & Letlotlo, 2019). The presence of *S. aureus* has a potential health risk to human health because it produces enterotoxins, leading to food poisoning and gastroenteritis (Mohamed et al., 2023). On the other hand, TPC in food acts as a hygiene and quality indicator. Their presence tells poor hygiene, possible contamination, and reduced product safety (Lambrechts et al., 2014). It means that printed papers used for wrapping the ready-to-eat fried foods were handled in unhygienic conditions, resulting in microbial contamination. These findings are consistent with several studies, such as that of Haurissa et al. (2024), who reported that unhygienic handling and improper storage conditions can hub microbes. According to Huo et al. (2023), wrapping hot food samples produces vapor, which, upon condensation, creates high relative humidity, making the food more susceptible to bacterial growth.

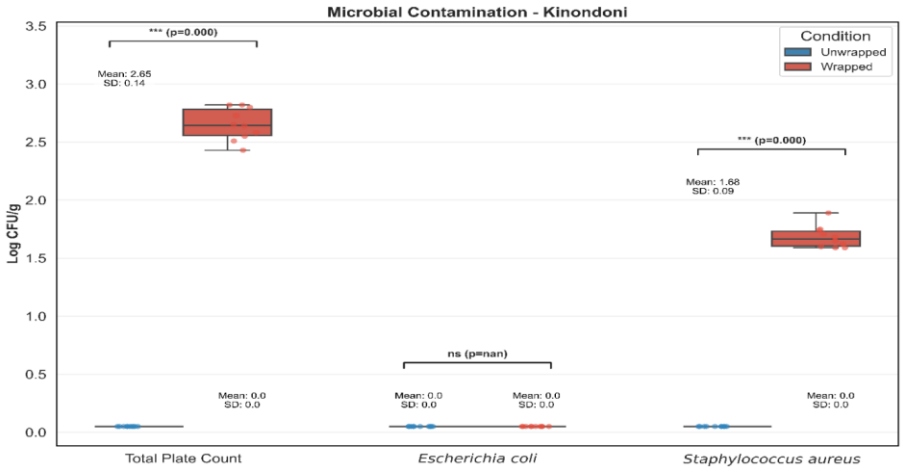

Figure 2. Microbial contamination in Kinondoni District.

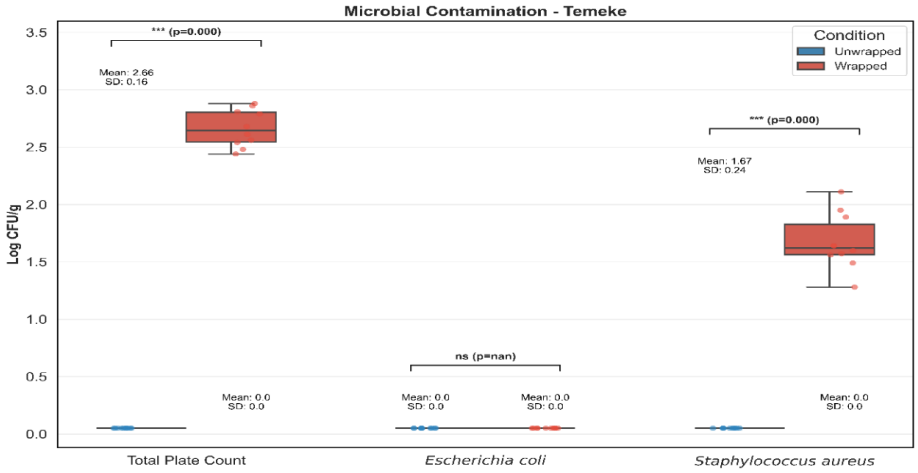

Figure 3. Microbial contamination in Temeke District.

Furthermore, *E. coli* was not detected in any of the samples, which might be attributed by its sensitivity to heat, as the organism can be inactivated or destroyed at 70 °C within approximately two minutes, whereas *S. aureus* was only detected in wrapped foods in all districts but not in unwrapped foods. Moreover, the results showed significant differences in microbial contamination between

wrapped and unwrapped samples across all districts ($p<0.05$). Moreover, storage and vending conditions might have been the factors contributing to microbial contamination, where wrapped food develops moisture, which tends to be trapped in the package being wrapped, creating a humid environment that supports microbial survival and growth. The results are also in line with the study by Hyun et al. (2018), who reported that microbial survival and growth depend on storage conditions, including storage temperature, relative humidity, and time.

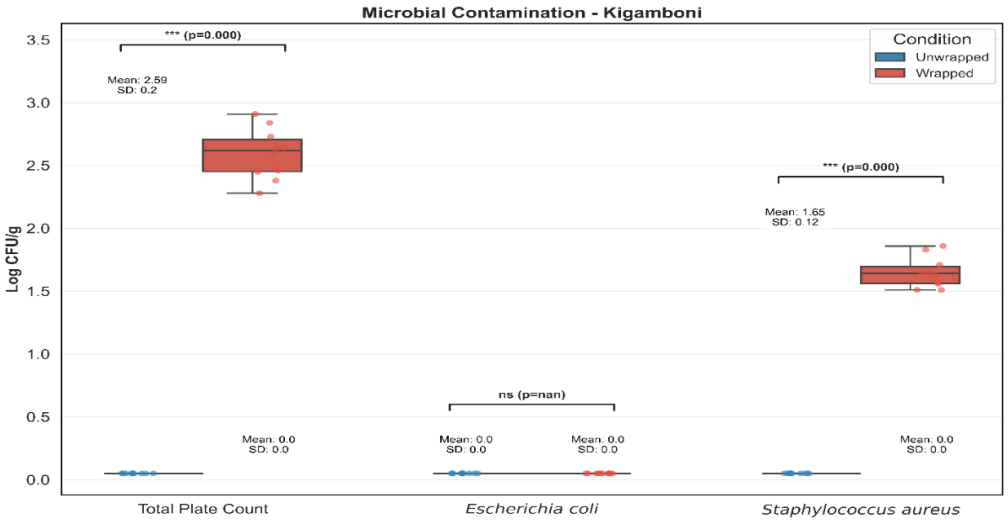

Figure 4. Microbial contamination in Kigamboni District.

Conclusion

The results revealed higher concentrations of heavy metals (Pb, Cr, and Cd) in the wrapped ready-to-eat fried foods across all study sites compared to unwrapped ones, with a significant difference between the two groups. Microbial contamination, as indicated by TPC and *S. aureus*, was significantly elevated in wrapped samples, whereas *E. coli* was undetected in both groups. The study recommends that government authorities, such TBS and local government authorities, through health officers, establish and enforce regulations that strictly restrict the use of printed papers, particularly newspapers, for wrapping ready-to-eat fried food, operational measures for street food preparation, storage and serving, develop regulatory frame works and standards for food contact materials suitable for street food in Tanzania, promote safer packaging materials and barrier technologies, Furthermore, it is essential to implement awareness campaigns and training programs for food vendors and the public regarding food safety and the hazards associated with printed paper. These initiatives should utilize various media platforms, including television, radio, and direct outreach.

Acknowledgments

The authors sincerely appreciate the financial support provided by the TBS for this research, as well as the valuable support from Sokoine University of Agriculture, Morogoro, Tanzania.

Conflicts of interest

The authors declare no conflicts of interest.

Disclaimer

Authors hereby declare that NO generative AI technologies, such as large language models (ChatGPT, COPILOT, etc.) and text-to-image generators, have been used during the writing or editing of this manuscript.

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