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ASSESSING LEVELS OF MONOSODIUM GLUTAMATE AND MICROBES IN STREET FOODS

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ABSTRACT
Purpose: This study aimed to assess monosodium glutamate (MSG) levels and microbial contamination in street-vended foods in Sunyani Township, Ghana. The study evaluated the safety of commonly consumed foods, such as soup, stew, noodles, and fried rice, and compared contamination levels between day and night samples. The excessive use of MSG and poor food hygiene in street-vended foods can pose significant health risks, including metabolic disorders, foodborne illnesses, and gastrointestinal issues. Despite the popularity of street foods, limited research has addressed the food safety risks in this context.
Design/Methodology/Approach: Twenty samples of four street foods were collected during day and night. High-performance liquid Chromatography (HPLC) was used to determine MSG concentrations, while microbial analysis focused on Total Viable Counts (TVC), Total Coliform Counts (TCC), and the presence of pathogens such as *Escherichia coli* and *Salmonella* using standard protocols.
Findings: MSG levels in all food samples exceeded the 10 g/kg Codex Alimentarius guideline, particularly in noodles (19.64 g/kg) and fried rice (19.52 g/kg) during night-time sales. Microbial contamination was higher at night, with TVC levels in some samples exceeding 5 log CFU/g, posing a risk of foodborne illness. Significant differences between day and night contamination levels were observed, especially for *E. coli* and *Salmonella*.
Research Limitation: This study considered only four types of street foods; hence, further research is needed to assess a broader range of street-vended products. Additionally, seasonal variations in contamination levels were not investigated.
Practical Implication: The findings highlight the need for enhanced regulatory oversight and vendor education on food safety and hygiene practices to reduce public health risks.
Social Implication: Improving food safety in street vending can protect public health, reduce healthcare costs, and improve the quality of life for consumers in urban settings.
Originality/ Value: This research provides valuable insights into the risks associated with MSG overuse and microbial contamination in street foods, contributing to the data on food safety in developing countries.

Keywords*: Food additive. food safety. microbes. monosodium glutamate. street foods*
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INTRODUCTION

Food safety is a serious concern worldwide, particularly in street-vended foods, popular in many developing countries due to their affordability, accessibility, and variety. However, the growing reliance on street foods has also raised concerns about the potential risks of using food additives and microbial contamination.

One commonly used food additive is monosodium glutamate (MSG), which enhances the flavour of foods but has been linked to various health concerns when consumed in high quantities (Afraa *et al.*, 2013). Alongside this, street-vended foods often lack the rigorous hygiene standards seen in more formalised food establishments, increasing the risk of microbial contamination and leading to foodborne illnesses (Torrens, 2013).

Monosodium Glutamate (MSG) is a sodium salt of the amino acid glutamic acid and has been used globally as a flavour enhancer since its discovery in 1909. While its use is deemed generally safe by organisations such as the Food and Drug Administration (FDA) and the World Health Organization (WHO), excessive consumption can pose health risks, such as neurotoxicity, obesity, and metabolic disorders (Mehreen *et al.*, 2012; WHO, 2011).

The maximum allowable concentration of MSG in food is regulated in many countries, with limits typically set at 10 g/kg (European Parliament and Council Directive, 1995). However, there is growing concern that street vendors may need to adhere to these limits, thereby increasing the risk to public health.

Monosodium glutamate (MSG) is widely used as a flavour enhancer in many street-vended foods. According to the Joint FAO/WHO Expert Committee on Food Additives (JECFA), MSG is considered safe when used at levels commonly found in foods. The acceptable daily intake (ADI) is "not specified," which means no maximum limit is needed for the substance (JECFA, 1987).

Also, the U.S. Food and Drug Administration (FDA) classified MSG as "generally recognised as safe" (GRAS). No specific limit is enforced for food use, but food labels must disclose their presence (FDA, 2012). A temporary ADI of 30 mg/kg body weight per day was suggested based on newer studies (EFSA, 2017). Exceeding this level in regular food consumption could lead to symptoms like headache, nausea, or discomfort. MSG is permitted as a flavour enhancer in specific food categories, and its maximum permissible levels vary depending on the product, typically around 10g/kg in some processed foods (Codex Alimentarius, 2023). Although the use of MSG is generally accepted within regulated limits, high levels of consumption have been associated with adverse health effects, including neurotoxicity, obesity, and metabolic disorders (Mehreen *et al.*, 2012). This study aims to assess the concentration of MSG in popular street foods such as fried rice, noodles, soups, and stews to evaluate whether these foods contain MSG within the allowable safety limits (Afraa *et al.*, 2013).

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The problem is exacerbated by the microbial contamination often occurring in street-vended foods. Pathogens such as *Escherichia coli*, *Staphylococcus* aureus, and *Salmonella* are commonly found in food sold on the street, posing significant public health risks (Bekele *et al.*, 2014). These pathogens are known to cause foodborne illnesses, and their presence in food signifies poor hygiene practices and the potential for serious health risks (Rane, 2011).

The microbial profiling will help determine the contamination levels in the collected food samples and assess the potential public health threats these microorganisms pose. Poor hygiene practices, inadequate food storage, and the open-air nature of street vending contribute to the proliferation of harmful microorganisms, making these foods a significant source of foodborne illnesses (Rane, 2011). In developing regions like Sunyani Township, street foods are often sold in environments where sanitation is inadequate, leading to heightened concerns about both MSG overuse and microbial contamination. Another key objective of this study is to assess the microbial safety of street-vended foods by identifying the presence of harmful microorganisms, particularly *Escherichia coli*, *Staphylococcus* aureus, and *Salmonella* (Bekele *et al.*, 2014).

Given the high consumption of street-vended foods in Sunyani Township, particularly by low-income groups, assessing the levels of MSG used and the presence of harmful microbes is essential. This study investigates the concentration of MSG and the extent of microbial contamination in various food samples from street vendors in Sunyani Township. The findings aim to inform policy recommendations to improve food safety standards and public health outcomes.

One of the hypotheses of this study is that the time of day affects the contamination levels in street-vended foods. It has been suggested that food sold at night is more prone to microbial contamination due to prolonged exposure to unsanitary conditions and the lack of proper storage facilities (Doménech-Sánchez *et al.*, 2011).

This study will compare MSG concentration and microbial contamination levels in foods sold during the day versus those sold at night to identify any significant differences. Two hypotheses were tested: Ho: There is no substantial disparity in the MSG concentrations of food sold during the day compared to those sold at night, and Ho: There is no substantial disparity in the bacterial contamination levels of food served during the day compared to those sold at night. The results from this study will contribute to a better understanding of the risks associated with street-vended foods and inform policy recommendations to enhance food safety in Sunyani Township.

LITERATURE REVIEW

This section reviews related literature on Monosodium Glutamate (MSG) and Microbial Contamination in Street Foods. It also touches on the health implications of MSG overuse and microbial contamination.

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Street Foods

Street food is an integral part of urban life, particularly in developing countries, offering affordable and diverse meal options to a broad demographic. Street food plays a vital role in the culinary landscape of urban areas, particularly in developing countries. It offers affordable meal options to people from various socio-economic backgrounds (Bhowmik, 2012; Tinker, 1997).

According to a Food and Agriculture Organization (FAO) study, approximately 2.5 billion people worldwide consume street food daily (FAO, 2018). However, regulatory oversight and inadequate hygienic practices pose significant food safety concerns (Mensah et al., 2012; Muinde & Kuria, 2015). Street food vendors often operate in unsanitary environments, increasing the risk of microbial contamination (Alimi *et al*., 2016; Sarkodie *et al*., 2014; Greig *et al*., 2007). Furthermore, the excessive use of food additives like monosodium glutamate (MSG) has been reported in various studies (Latham, 2010; Neil, 2013).

The dual challenges of microbial contamination and excessive use of food additives pose substantial public health risks. Studies have shown that street food can be a significant source of foodborne illnesses, including cholera, typhoid, and dysentery (Harris *et al*., 2017; Kilonzo-Nthenge *et al*., 2015). Moreover, the excessive consumption of MSG has been linked to various health problems, including obesity, diabetes, and cardiovascular disease (Latham, 2010; Neil, 2013).

Excessive Use of Monosodium Glutamate in Street Foods

Monosodium glutamate (MSG), a sodium salt of the amino acid glutamic acid, is a widely utilised flavour enhancer in foods globally. Regulatory authorities such as the U.S. Food and Drug Administration (FDA) and the Joint FAO/WHO Expert Committee on Food Additives (JECFA) have deemed MSG generally recognised as safe (GRAS) when used within established limits (FDA, 2012; WHO, 2011). Despite its safety classification, excessive MSG consumption raises health concerns, including metabolic disorders, neurotoxicity, and obesity (Mehreen *et al*., 2012).

The health risks associated with excessive MSG consumption, such as obesity, neurotoxicity, and metabolic disorders, have been extensively documented (Kwok *et al*., 2017). Despite its "generally recognised as safe" status, emerging research advocates for stricter regulatory oversight and public awareness to mitigate potential long-term health effects. The Codex Alimentarius guideline sets a maximum threshold of 10 g/kg for processed foods.

Nevertheless, studies indicate this limit is often exceeded in informal food settings, such as street-vended foods (Codex Alimentarius, 2023). MSG levels in street vended foods surpass the recommended safety limits and pose risks of adverse health outcomes, particularly with frequent

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consumption (Abd-Elhaleem *et al.*, 2020). In Egypt, MSG concentrations in fast foods like shawarma ranged from 10 g/kg to 13 g/kg, further emphasising the prevalence of unregulated use of this additive (Abd-Elhaleem *et al.*, 2020).

Microbial Contamination in Street Foods

Street-vended foods are integral to urban economies, offering affordable and convenient meal options. However, these foods often fail to meet acceptable hygiene standards, increasing the risk of microbial contamination. Microbial contamination in street-vended foods is a recurring theme in food safety studies. Total Viable Count (TVC), Total Coliform Count (TCC), and presence of pathogens such as *Escherichia coli* (*E. coli*), *Staphylococcus aureus*, and *Salmonella* provide benchmarks for assessing contamination levels (ICMSF, 2002).

Studies have highlighted the prevalence of pathogens such as, *E. coli, Staphylococcus aureus*, and *Salmonella* in street foods, attributing contamination to inadequate food storage, poor handling practices, and prolonged exposure to environmental contaminants (Bekele *et al.*, 2014; Rane, 2011). Pathogens in street foods pose a substantial risk for foodborne illnesses. High *E. coli* counts, indicative of fecal contamination, have been consistently reported in developing regions.

In Dhaka, Bangladesh, Al Mamun *et al.* (2012) documented *E. coli* levels in noodles ranging from 2.5 to 3.2 $\log_{10}$ CFU/g. Mehreen *et al.* (2012) further emphasise the prevalence of such risks in vulnerable populations, including children and those with underlying health conditions. In a previous study in Kenya, microbial contamination was notably higher in night-time samples compared to day-time ones; specifically, Total Viable Counts (TVC) in noodles exceeded the acceptable 5 log CFU/g threshold during night sales (Muinde & Kuria, 2015). These elevated bacterial loads underscore the impact of prolonged exposure and lack of refrigeration during vending hours.

Health Implications of MSG Overuse and Microbial Contamination

Overusing MSG and microbial contamination in street foods poses significant public health challenges. This intersection of excessive MSG use and microbial contamination underscores a dual threat to public health in regions reliant on street-vended foods like Ghana. Excessive MSG intake can lead to symptoms such as nausea, headaches, and long-term metabolic complications, particularly in sensitive individuals (EFSA, 2017). Similarly, microbial contamination with pathogens such as *E. coli* and *Salmonella* increases the risk of foodborne illnesses, including gastroenteritis and salmonellosis, especially concerning in developing regions where healthcare resources may be limited (WHO, 2015). Given these risks, regulatory oversight and education of street food vendors are critical to improving food safety standards. Policies enforcing hygiene practices and regulating additive use could mitigate the public health risks associated with street-vended foods (Mensah *et al.*, 2012).

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METHODOLOGY

This study employed an experimental design to analyse monosodium glutamate (MSG) levels and assess microbial contamination in street-vended foods collected from Sunyani Township. The methodology involved the following key processes: sample collection, chemical analysis of MSG, and microbial analysis. The experimental approach was chosen to provide quantitative data on MSG concentration and the incidence of harmful microorganisms in the sampled foods.

Sample Collection

Twenty (20) food samples were collected from various street food vendors across Sunyani Township. The selected foods were those most commonly sold by vendors, including fried rice, noodles, stews, and soups. The samples were collected during the daytime and nighttime, once a week for over five weeks, to assess any differences in MSG levels and microbial contamination based on the time of day. The collection process involved taking food samples in sterilised closed containers to avoid contamination during transportation to the laboratory. To ensure the data was representative and reliable, each sample was taken from different portions in bulk at the vending site (Bekele *et al.,* 2014). All food samples were analysed within two hours of collection to the laboratory.

Chemical Analysis of Monosodium Glutamate (MSG)

The High-Performance Liquid Chromatography (HPLC) method was used to determine the levels of MSG in the collected food samples. HPLC is a widely accepted method for analysing food additives due to its sensitivity, reproducibility, and ability to separate complex mixtures of food compounds (Mehreen *et al.*, 2012).

The MSG analysis was performed according to the procedure outlined by Afraa *et al.* (2013), which involved the derivatisation of MSG with dinitrofluorobenzene (DNFB) and subsequent injection into the HPLC system. The MSG in each food sample was quantified using a standard calibration curve prepared by injecting known concentrations of MSG into the HPLC system.

The mobile phase used was a methanol-water mixture (1:1), and the samples were analysed under the following conditions: a reverse-phase C18 column, detection at 254 nm, and a flow rate of 1.2 ml/min (Afraa *et al.*, 2013). The concentration of MSG in each sample was determined based on the peak area of the MSG and compared to the standard curve. All samples were analysed in triplicate to ensure accuracy and reliability.

Microbial Analysis

Microbial analysis was performed to identify the presence of key foodborne pathogens such as *Escherichia coli*, *Staphylococcus* aureus, and *Salmonella*. The microbial assessment followed standard laboratory protocols, using selective agar media for isolating and identifying the microorganisms in the food samples (Bekele *et al.*, 2014). *Escherichia coli* (*E. coli*) was isolated

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using MacConkey agar, allowing differentiated *E. coli* based on its characteristic pink colonies (Doménech-Sánchez *et al.*, 2011). *Staphylococcus* aureus was isolated using Mannitol Salt Agar (MSA). The sight of yellow colonies designated the existence of *Staphylococcus* species (Argudin *et al.*, 2010). *Salmonella* was detected using *Salmonella*-Shigella Agar (SSA). The cream-coloured colonies with black centres indicated *Salmonella* presence (Doménech-Sánchez *et al.*, 2011).

The Total Viable Count (TVC) method was used to quantify the overall microbial load in the food samples. TVC was performed by inoculating diluted food samples onto Plate Count Agar (PCA) and incubating the plates at 35°C for 24 hours (Minnesota Department of Health, 2013). The outcomes were quantified as colony-forming units (CFU) per gram of the dietary sample. The results from the microbial analysis were compared to acceptable food safety standards to determine whether the contamination levels exceeded recommended limits (Bekele *et al.*, 2014). In addition, microbial contamination levels were compared between food samples collected during the day and those collected at night to identify any time-related differences in food safety.

Data analysis

The quantitative data derived from the chemical analysis of MSG and the microbiological analysis were analysed statistically using Statistical Package for Social Sciences (SPSS) version 26.0. The data were evaluated by t-test to ascertain significant differences in MSG concentrations and microbial contamination levels across food categories at various intervals. Descriptive statistics , including mean values and standard deviations, were computed to summarise the results.

RESULTS & DISCUSSION

Monosodium glutamate (MSG) levels in samples

Table 1 outlines the monosodium glutamate (MSG) concentrations in the samples (soup, stew, noodles, and fried rice) during night and day periods. The MSG levels in the soup sample varied from 14.35 to 15.01 g/kg at night and from 12.44 to 12.79 g/kg during the day (Table 1). The average nighttime MSG (14.72 g/kg) and daytime MSG (12.49 g/kg) both surpass the typical maximum MSG threshold of 10 g/kg established for certain processed foods by Codex Alimentarius (Codex Alimentarius, 2023). For the stew samples, MSG levels ranged from 9.79 to 9.96 g/kg at night and 10.78 to 10.98 g/kg during the day (Table 1). The mean MSG concentration in daytime samples is significantly higher, indicating that stew consumed during the day may be marginally more MSG-rich than at night.

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Table 1: MSG levels (g/kg) in various food samples

Week/S.ID)	Sample/time of day							
	Soup		Stew		Noodles		Fried Rice	
	Day	Night	Day	Night	Day	Night	Day	Night
1	12.44	14.35	10.78	9.94	14.35	19.80	19.47	19.61
2	12.61	14.89	10.89	9.86	14.62	19.34	19.58	19.54
3	12.79	15.01	10.92	9.79	14.45	19.74	19.38	19.55
4	12.52	14.66	10.98	9.82	14.68	19.65	19.23	19.32
5	12.57	14.69	10.85	9.96	14.57	19.69	19.50	19.42
Ranges	12.44-12.79	14.35-15.01	10.78-10.98	9.79-9.96	14.35-14.68	19.34-19.80	19.23-19.58	19.32-19.61
Mean±SD	12.59±0.13	14.72±0.26	10.88±0.07	9.87±0.06	14.53±0.13	19.64±0.17	19.43±0.13	19.49±49
t-test	20.947		25.765		38.784		1.048	
p-value	0.001		0.03		0.001		0.68	

MSG: Monosodium glutamate; SD: standard deviation; S.ID: Sample Identification

The result in Table 1 indicates that the MSG concentrations in night-time noodles (19.64 g/kg) and day-time noodles (14.53 g/kg) significantly surpass the standard guideline of 10 g/kg (Codex Alimentarius, 2023). The nighttime noodles are especially alarming, as they exceed the threshold often regarded as tolerable by international regulations, thus presenting a health hazard if ingested frequently in substantial amounts. The fried rice samples predominantly exhibited elevated MSG concentrations (Table 1). The MSG concentrations in night-time fried rice (19.52 g/kg) and day-time fried rice (19.40 g/kg) substantially exceed the Codex guideline of 10 g/kg (Codex Alimentarius, 2023). This indicates that the fried rice samples exhibit elevated MSG levels over both periods, perhaps raising concerns regarding dietary overconsumption of MSG.

Significant differences exist between nighttime and day samples for soup, stew, and noodles ($p < 0.05$). No substantial difference exists in fried rice samples between night and day ($p > 0.05$) (Table 1). This outcome indicates that the cooking or serving circumstances for soup, stew, and noodles may differ markedly between day and night, although fried rice MSG levels remain the same. The results align with the findings of Abd-Elhaleem *et al.* (2020), which indicated elevated levels of MSG in street-vended foods in Egypt, especially in fast foods such as shawarma and fried chicken. Their research identified MSG concentrations ranging from 10 g/kg to 13 g/kg, which aligns with the findings from Sunyani Township.

The elevated MSG levels in certain meals may result in chronic health consequences, particularly with frequent use. A further study by Kwok *et al.* (2017) highlighted comparable findings, indicating that street food vendors frequently utilise MSG in quantities exceeding permissible levels due to insufficient regulation and understanding of its health hazards.

Further, the findings of this study align with a previous investigation of free and natural glutamate concentrations in several meals, which ranged from 2.3 to 12.7 g/kg (Steve & Susan, 2003). The present findings, however, contradict a study that examined Pakistani spice brands, which had significantly elevated MSG levels ranging from 27.0 to 88.0 g/kg (Mehreen *et al.*, 2012). The

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persistently elevated MSG levels in food samples, particularly in noodles and fried rice, are above the 10 g/kg standard at all times of day, which is alarming. Though MSG is generally innocuous, excessive ingestion might cause problems (severe neurological and metabolic diseases, cephalalgia, diaphoresis, and erythema) in vulnerable individuals or those sensitive to it.

Microbial quality of the food samples

Table two depicts the results of microbial contamination in the four street foods: soup, stew, noodles, and fried rice. Samples were collected both day and night.

The Total Viable Counts (TVC), which reflect the overall bacterial load in the food samples, showed variation ($p < 0.05$) between day and night for each type of food except for the stew sample ($p > 0.05$) (Table 2). Across the different food samples, TVC values were generally higher in foods sold at night. The range of TVC values in soup samples during the day was 4.95 to 5.18 log_{10} CFU/g, whereas the night-time values ranged from 5.28 to 5.48 log_{10} CFU/g. For stew, the daytime TVC ranged between 4.30 and 4.75 log_{10} CFU/g; at night, the values increased from 4.05 to 4.86 log_{10} CFU/g (Table 2).

For noodles, daytime TVC values ranged from 3.60 to 4.32 log_{10} CFU/g, while night-time samples showed higher counts between 4.60 and 5.20 log_{10} CFU/g. Similarly, fried rice exhibited higher TVC values at night, ranging from 4.65 to 5.20 log_{10} CFU/g, compared to 3.95 to 4.89 log_{10} CFU/g during the day. These results suggest a statistically significant increase in bacterial load in foods sold at night, with p-values indicating significant differences in TVC levels in soup ($p = 0.002$), noodles ($p = 0.001$), and fried rice ($p = 0.01$), but not in stew ($p = 0.46$) (Table 2).

According to the International Commission on Microbiological Specifications for Foods (ICMSF), acceptable TVC levels for ready-to-eat foods should generally not exceed 5 log_{10} CFU/g (ICMSF, 2005). Similarly, The European Food Safety Authority (EFSA) also recommends that ready-to-eat foods, especially those exposed to the open environment, should maintain TVC levels below 5 log_{10} CFU/g to prevent the proliferation of harmful bacteria (EFSA, 2011).

In this study, foods such as noodles and fried rice exceeded this limit during night-time sales, with some night-time values reaching 5.20 log_{10} CFU/g. Exceeding this threshold increases the risk of foodborne illnesses, especially when combined with the presence of specific pathogenic bacteria such as *Escherichia coli* and *Staphylococcus* aureus, both of which were also detected in this study (Bekele *et al.*, 2014).

The Total Coliform Count (TCC), which measures the presence of coliform bacteria (indicators of faecal contamination), revealed that coliform levels were higher at night for all food types. However, the difference was more pronounced in soup and noodles. The soup samples had daytime

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TCC values ranging from 3.89 to 4.41 log_{10} CFU/g, whereas the night-time values ranged from 4.40 to 4.80 log_{10} CFU/g. Noodles showed a daytime range of 2.15 to 2.49 log_{10} CFU/g and night-time values between 2.60 and 2.95 log_{10} CFU/g (Table 2).

Interestingly, fried rice exhibited a marked difference between day and night TCC, with values ranging from 3.81 to 4.60 log_{10} CFU/g during the day and 4.25 to 4.60 log_{10} CFU/g at night. Statistically significant differences were found in soup ($p = 0.0017$) and noodles ($p = 0.0082$), while stew and fried rice showed no significant differences ($p = 0.28$ and $p = 0.12$, respectively). International food safety standards suggest that ready-to-eat foods should have a TCC of less than 3 log_{10} CFU/g to be considered safe for human consumption (WHO/FAO, 2007; Codex Alimentarius Commission, 2019).

The results from Sunyani, especially for soup and noodles at night, showed TCC values between 4.40 and 4.80 log_{10} CFU/g and 2.60 and 2.95 log_{10} CFU/g, respectively, clearly exceed these safety limits. This indicates a heightened risk of foodborne illnesses such as diarrhoea and gastroenteritis due to faecal contamination in these foods, particularly during night sales (WHO/FAO, 2007). The results in Table 2 show that staphylococcal counts were higher in night-time samples, particularly in noodles and fried rice. For instance, noodles showed daytime counts ranging from 2.72 to 2.84 log_{10} CFU/g, while night-time counts ranged between 3.08 to 3.56 log_{10} CFU/g. Similarly, fried rice had daytime staphylococcal counts ranging from 3.24 to 3.61 log_{10} CFU/g, compared to night-time counts of 3.40 to 3.74 log_{10} CFU/g.

There were significant differences between day and night contamination levels for noodles ($p = 0.005$) and fried rice ($p = 0.04$), indicating a greater risk of staphylococcal contamination in food sold at night. For soup and stew, the differences in staphylococcal contamination were not statistically significant ($p = 0.27$ and $p = 0.30$, respectively) (Table 2). The counts observed in the current study, mainly the night-time counts for noodles and fried rice, exceed this threshold of 2 log_{10} CFU/g (WHO, 2015), suggesting that food sold in these conditions could pose a significant health risk to consumers. Table 2 shows that the daytime *Salmonella* count in soup samples ranged from 4.23 to 4.62 log_{10} CFU/g, and the nighttime count ranged from 4.33 to 4.77 log_{10} CFU/g. The stew samples also demonstrated slightly higher contamination levels at night (3.95 to 4.80 log_{10} CFU/g) compared to daytime values (3.91 to 4.51 log_{10} CFU/g).

Noodles had relatively low *Salmonella* counts during the day, ranging from 2.69 to 2.83 log_{10} CFU/g, while the night-time counts were marginally higher, ranging from 2.81 to 2.94 log_{10} CFU/g. Fried rice showed similar trends. Statistically significant differences were observed in the *Salmonella* levels of stew samples ($p = 0.03$), while there were no significant differences in the other food types. The levels of *Salmonella* detected in the current study far exceed the acceptable

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limits, i.e., foods must be free from detectable *Salmonella* in a 25 g sample (WHO, 2010), particularly in soup and stew, which raises significant public health concerns.

Table 1: Microbiological load (log cfu/g) in the various food samples

Microbial characteristics	Week/S.ID	Sample/time of day							
		Soup		Stew		Noodles		Fried Rice	
		Day	Night	Day	Night	Day	Night	Day	Night
Total Viable Counts (TVC)	**1**	5.02	5.45	4.45	4.21	3.90	5.11	4.05	4.90
	2	5.18	5.48	4.52	4.05	4.20	4.91	4.50	5.05
	3	4.95	5.37	4.75	4.30	4.10	5.20	4.01	5.12
	4	5.11	5.28	4.30	4.50	3.60	4.60	4.89	4.65
	5	5.05	5.42	4.32	4.86	4.32	4.82	3.95	5.20
	Ranges	4.95 - 5.18	5.28 - 5.48	4.30 - 4.75	4.05 - 4.86	3.60 - 4.32	4.60 - 5.20	3.95 - 4.89	4.65 - 5.20
	Mean±SD	5.06±0.09	5.48±0.08	4.47±0.17	4.21±0.29	4.02±0.26	4.93±0.23	4.28±0.37	4.98±0.22
	p-value	*0.002*		*0.46*		*0.001*		*0.01*	
Total Coliform Count (TCC)	**1**	4.32	4.40	2.24	2.27	2.15	2.85	4.02	4.35
	2	4.18	4.65	2.21	2.24	2.35	2.95	4.48	4.55
	3	4.41	4.75	2.27	2.21	2.25	2.75	3.81	4.51
	4	4.14	4.50	2.18	2.28	2.49	2.60	4.28	4.60
	5	3.89	4.80	2.30	2.29	2.42	2.90	4.60	4.25
	Ranges	3.89-4.41	4.40-4.80	2.18-2.30	2.21-2.29	2.15-2.49	2.60-2.95	3.81-4.60	4.25-4.60
	Mean±SD	4.19±0.18	4.62±0.17	2.24±0.04	2.26±0.03	2.33±0.14	2.81±0.13	4.24±0.24	4.45±0.14
	p-value	*0.0017*		*0.28*		*0.0082*		*0.12*	
Staphylococcus	**1**	4.21	4.12	3.81	3.97	2.78	3.14	3.45	3.74
	2	4.03	4.09	4.27	3.88	2.72	3.25	3.34	3.64
	3	4.45	4.30	3.72	4.29	2.84	3.08	3.52	3.55
	4	3.96	3.99	4.10	4.11	2.75	3.56	3.61	3.40
	5	3.82	4.43	3.53	3.62	2.80	3.18	3.24	3.67
	Ranges	3.82 - 4.45	3.99 - 4.43	3.53 - 4.27	3.62 - 4.29	2.72 - 2.84	3.08 - 3.56	3.24 - 3.61	3.40 - 3.74
	Mean±SD	4.09±0.24	4.19±0.17	3.89±0.29	4.00±0.26	2.78±0.05	3.24±0.20	3.43±0.13	3.60±0.11
	p-value	*0.27*		*0.30*		*0.005*		*0.04*	
Salmonella	**1**	4.23	4.77	4.51	4.45	2.77	2.94	3.35	3.44
	2	4.62	4.33	3.91	3.95	2.83	2.81	3.57	3.31
	3	4.52	4.64	4.02	4.25	2.75	2.88	3.42	3.53
	4	4.33	4.45	4.35	4.80	2.69	2.85	3.59	3.49
	5	4.51	4.57	4.11	4.30	2.71	2.93	3.30	3.39
	Ranges	4.23-4.62	4.33-4.77	3.91-4.51	3.95-4.80	2.69-2.83	2.81-2.94	3.30-3.59	3.31-3.53
	Mean±SD	4.44±0.16	4.55±0.17	4.18±0.23	4.35±0.30	2.75±0.05	2.88±0.05	3.45±0.11	3.43±0.08
	p-value	*0.25*		*0.31*		*0.03*		*0.79*	
EEscherichia coli	**1**	4.52	4.95	3.87	4.00	2.40	3.00	4.25	4.18
	2	4.15	5.21	4.25	3.75	2.18	3.32	3.91	4.35

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3	4.71	5.06	3.67	4.05	2.45	2.68	4.12	3.98
4	4.38	5.35	4.10	4.11	2.22	2.85	3.81	4.25
5	4.62	4.82	3.98	3.92	2.34	3.20	4.10	4.08
Ranges	4.15-4.71	4.82-5.35	3.67-4.25	3.75-4.11	2.18-2.45	2.68-3.32	3.81-4.25	3.98-4.35
Mean±SD	4.48±0.21	5.08±0.20	3.97±0.22	3.97±0.13	2.32±0.12	3.01±0.25	4.04±0.16	4.17±0.13
p-value	*0.002*		*0.99*		*0.001*		*0.12*	

The significance level was at p=5%

For example, contamination levels exceeding 4 log_{10} CFU/g in ready-to-eat food indicate serious risks for foodborne illnesses, including salmonellosis (WHO, 2010). The *Escherichia coli* (*E. coli*) counts, which indicate faecal contamination, were notably higher in night-time samples across all food types. Soup showed *E. coli* counts ranging from 4.15 to 4.71 log_{10} CFU/g during the day and 4.82 to 5.35 log_{10} CFU/g at night. In stew, daytime *E. coli* counts ranged between 3.67 and 4.25 log_{10} CFU/g, while night-time values were between 3.75 and 4.11 log_{10} CFU/g (Table 2).

For noodles, daytime *E. coli* counts ranged from 2.18 to 2.45 log_{10} CFU/g, with higher night-time counts ranging from 2.68 to 3.32 log_{10} CFU/g. Fried rice showed a similar pattern, with daytime *E. coli* counts between 3.81 and 4.25 log_{10} CFU/g and night-time values ranging from 3.98 to 4.35 log_{10} CFU/g. The p-values for *E. coli* counts in soup ($p = 0.002$) and noodles ($p = 0.001$) indicated significant differences between day and night contamination levels. *E. coli* counts above 2 log_{10} CFU/g are considered unsafe for consumption according to the International Commission on Microbiological Specifications for Foods (ICMSF), which sets thresholds for acceptable microbial levels in ready-to-eat foods (ICMSF, 2002). The World Health Organization (WHO) also states that food containing *E. coli* counts exceeding 3 log CFU/g poses a high risk of foodborne illnesses, including gastroenteritis, which can lead to severe health issues, especially in vulnerable populations (WHO, 2012).

Hypothesis testing

Null Hypothesis 1 (H_0): There is no significant difference in the MSG levels of food sold during the day and those sold at night.

Evaluation: The study results indicate significant differences in MSG levels (g/kg) between day and night for certain foods, as shown in Table 1. For example, Soup: Nighttime MSG levels ranged from 14.35 to 15.01 g/kg compared to 12.44 to 12.79 g/kg during the day, with an average nighttime MSG of 14.72 g/kg and daytime MSG of 12.49 g/kg. Noodles: Nighttime MSG levels were 19.64 g/kg, significantly higher than the daytime level of 14.53 g/kg. Statistical Analysis: p-values for MSG level differences in soup and noodles were $p < 0.05$, indicating significant variation between day and night samples. Consequently, we reject Null Hypothesis 1 (H_0), as there

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is a statistically significant difference in MSG levels between daytime and nighttime samples for specific foods, particularly soup and noodles.

Null Hypothesis 2 (H_0): There is no significant difference in the bacterial contamination levels of food sold during the day and those sold at night.

Evaluation: The microbial analysis results show higher bacterial contamination levels at night for most food samples. From Table 2, Total Viable Counts (TVC): For instance, nighttime TVC levels in soup ranged from 5.28 to 5.48 log CFU/g, while daytime values were lower at 4.95 to 5.18 log CFU/g. *Escherichia coli* and *Staphylococcus* aureus: *E. coli* contamination was notably higher at night in soup and noodles, with p-values of $p = 0.002$ for soup and $p = 0.001$ for noodles, indicating significant differences. Statistical Analysis: Significant p-values ($p < 0.05$) for TVC in soup, noodles, and fried rice further suggest substantial differences in bacterial contamination levels based on the time of sale. We, therefore, reject Null Hypothesis 2 (H_0), as there is a statistically significant increase in bacterial contamination at night for specific food types, showing that time of day impacts contamination levels.

Discussion

The observed TVC range for soup during the day (4.95 to 5.18 $\log_{10}$ CFU/g) and at night (5.28 to 5.48 $\log_{10}$ CFU/g) is comparable to findings by Muinde and Kuria (2015), who reported similar TVC values in street-vended soups in Nairobi, Kenya. In their study, TVC values ranged between 4.5 and 5.5 $\log_{10}$ CFU/g, particularly in foods exposed to poor handling practices and prolonged exposure to environmental contaminants, supporting the assertion that bacterial contamination increases significantly in open-air food environments. This increased bacterial load during night-time vending can be attributed to extended food exposure to unsanitary conditions, such as contact with dust, flies, and handling by multiple customers (Rane, 2011).

For noodles, the daytime TVC values (3.60 to 4.32 $\log_{10}$ CFU/g) and night-time TVC values (4.60 to 5.20 $\log_{10}$ CFU/g) align closely with a study conducted by Mensah *et al.* (2012) in Ghana. Their study found TVC levels of 4.0 to 5.3 $\log_{10}$ CFU/g in noodles sold at night, particularly when food handling practices were less regulated, and vendors lacked access to proper food storage facilities.

Similarly, Carrasco *et al.* (2012) noted that TVC levels in noodle-based dishes increased when foods were unrefrigerated for long periods, particularly in open-market settings, supporting the trend observed in this study that food sold at night is more prone to contamination. The TVC results for fried rice in this study, which ranged from 3.95 to 4.89 $\log_{10}$ CFU/g during the day and 4.65 to 5.20 $\log_{10}$ CFU/g at night, are also consistent with Feglo and Sakyi (2012), who reported similar findings for street-vended fried rice in Kumasi, Ghana. Their study found night-time TVC

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levels of 4.5 to 5.5 log_{10} CFU/g, which they attributed to poor temperature control and longer food exposure times at night.

Prior studies indicate bacterial proliferation intensifies when food is maintained at room temperature for extended durations without refrigeration (Feglo & Sakyi, 2012). This also could be because night-time vendors often lack refrigeration and rely on open-air storage. The statistically significant increase in TVC values between day and night for foods such as fried rice and noodles underscores the importance of controlling environmental factors and adhering to food safety practices to mitigate bacterial growth. The TCCs observed in the current study are consistent with those of Mensah *et al.* (2012), who reported elevated levels of coliform bacteria in street-vended foods in Accra, Ghana, particularly those sold in the evening. The coliform counts exceeded 3 log_{10} CFU/g in most evening samples, indicating a higher risk of faecal contamination due to prolonged exposure to unsanitary environments and inadequate food handling practices during vending hours (Mensah *et al.*, 2012).

Another study by Chukuezi (2010), conducted in Owerri, Nigeria, reported that street foods had TCC values ranging between 3.0 and 4.5 log_{10} CFU/g, which aligns with the current findings in Sunyani. The study highlighted that contamination levels were significantly higher during the evening, especially for foods such as soups and stews, frequently reheated but improperly stored during vending hours. The author attributed the elevated night-time coliform counts to vendors' poor hygiene practices and lack of refrigeration, which fosters bacterial growth.

Moreover, a study by Muinde and Kuria (2015) in Nairobi, Kenya, found that coliform levels in foods sold by street vendors often exceeded 3.5 log_{10} CFU/g, particularly in evening samples. Their findings corroborate the results of this study, where the TCC for noodles and soup was significantly higher in the night-time samples. This pattern is troubling, given the established links between coliform contamination and foodborne illnesses (Rane, 2011).

The study revealed that staphylococcal counts were significantly higher in night-time noodles and fried rice samples than in daytime samples. Mensah *et al.* (2012) reported similar results in their study of street foods in Accra, Ghana, where they observed that staphylococcal contamination was more prevalent in foods stored or sold under unsanitary conditions at night. Their study found staphylococcal counts as high as 3.80 log_{10} CFU/g in some night-time food samples, which aligns with the 3.08 to 3.56 log_{10} CFU/g range found in the current study for noodles.

Muinde and Kuria (2015) studied street-vended foods in Nairobi, Kenya. They found staphylococcal counts ranging from 3.0 to 4.5 log_{10} CFU/g in fried foods, particularly those exposed to the open air for long periods. Their findings are comparable to the 3.40 to 3.74 log_{10} CFU/g staphylococcal contamination range found in fried rice at night in the current study. Also,

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Argudin *et al.* (2010) examined the contamination of ready-to-eat foods with *Staphylococcus* aureus in Europe.

Like the current study, they reported staphylococcal counts ranging from 2.0 to 4.5 $\log_{10}$ CFU/g in foods sold by street vendors, particularly during the evening hours. In a study conducted by Mensah *et al.* (2012) on street foods in Accra, Ghana, *Salmonella* contamination was prevalent in foods containing meat and poultry, with counts ranging between 3.50 and 4.70 $\log_{10}$ CFU/g. This range is similar to the findings in the current study, particularly for soup and stew samples. Another study by Rane (2011), which assessed street food safety in India, reported *Salmonella* counts in cooked foods between 2.50 and 4.20 $\log_{10}$ CFU/g.

Similar to the present findings, Rane noted that *Salmonella* contamination was higher in foods exposed for longer durations without proper storage, particularly at night. The study by Carrasco *et al.* (2012) on the cross-contamination of *Salmonella* in ready-to-eat foods further supports the findings of this research. Carrasco's study showed that cross-contamination from raw ingredients or improper food handling can result in *Salmonella* counts as high as 4.5 $\log_{10}$ CFU/g, which aligns with the nighttime contamination levels observed in soup and stew in Sunyani.

The *E. coli* contamination observed in noodles and fried rice in this study is consistent with findings from Al Mamun *et al.* (2013), who studied street food contamination in Dhaka, Bangladesh. Their research reported *E. coli* levels in noodles ranging from 2.5 to 3.2 log CFU/g, which mirrors the 2.68 to 3.32 log CFU/g range found in the current study's night-time noodle samples. Fried rice, another commonly consumed street food, also showed *E. coli* counts that were in line with findings from previous studies. Rane (2011), in a study of street foods in Mumbai, India, found *E. coli* contamination in fried rice samples to range between 3.5 and 4.0 log CFU/g, which closely matches the 3.81 to 4.35 log CFU/g observed in the current study. Both studies emphasise that fried rice is particularly prone to contamination due to its frequent reheating and the use of leftover rice, practices that create opportunities for bacterial growth.

CONCLUSION

The study sought to study the monosodium glutamate (MSG) concentrations and microbial contamination levels in popular street-vended foods in Sunyani Township. The study identified that MSG levels in all food samples, including soup, stew, noodles, and fried rice, consistently exceeded the Codex Alimentarius guideline of 10 g/kg, particularly in noodles and fried rice, which showed concentrations as high as 19.64 g/kg and 19.52 g/kg, respectively, during nighttime sales. Such elevated levels of MSG may pose potential health risks, including neurological disorders and metabolic issues, especially with frequent consumption. The significant differences

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in MSG levels between day and night for certain foods, such as soup and noodles, suggest varying preparation or serving practices depending on the time of day.

Regarding microbial contamination, the study revealed that Total Viable Counts (TVC) and Total Coliform Count (TCC) levels were generally higher in foods sold at night. Noodles and fried rice exhibited TVC values exceeding the recommended 5 log_{10} CFU/g limit set by the International Commission on Microbiological Specifications for Foods (ICMSF) and the European Food Safety Authority (EFSA), particularly during night-time sales. The elevated microbial load in night-time samples indicates poor hygiene practices and inadequate food storage, increasing the risk of foodborne illnesses such as gastroenteritis and diarrheal diseases.

Additionally, *Escherichia coli* (*E. coli*) and *Salmonella* in various samples raise significant public health concerns. The *E. coli* counts in day and night samples of soup, noodles, and fried rice exceeded the ICMSF and World Health Organization (WHO) safety limits of 2-3 log CFU/g for ready-to-eat foods. These elevated levels, especially in night-time samples, indicate faecal contamination, which can lead to serious health issues, particularly in vulnerable populations. The *Salmonella* counts in soup and stew samples, which exceeded 4 log CFU/g, further highlight the need for stricter food safety measures to prevent outbreaks of salmonellosis.

This study highlights the urgent need for improved regulation and training for street food vendors to ensure compliance with food safety standards. Regular inspections by local health authorities and increased public awareness about the risks associated with excessive MSG consumption and microbial contamination are essential to mitigate the health risks posed by street-vended foods in Sunyani Township. Future research should investigate the long-term health effects of chronic MSG exposure and develop targeted interventions to enhance food safety in the informal food sector.

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