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Research Article

Evaluation of Food Safety Knowledge Among Food Service Workers and Microbial Contamination of Food Contact Surfaces in University Restaurants in Morogoro Tanzania

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Abstract

Foodborne illnesses, a significant global health concern, are primarily attributable to microbial contamination. Inadequate food handling, substandard safety measures, and a lack of awareness exacerbate this issue. This study aimed to evaluate the food safety knowledge of food service workers and the microbial status of food contact surfaces in university restaurants in Morogoro Municipality, Tanzania. A cross-sectional study was conducted, employing a structured questionnaire and observational checklist. A total of 40 food service workers from four University restaurants participated. Standard methodologies for microbial analysis were employed to determine the Total Viable Count and Total Coliform Count, which indicated the degree of microbiological contamination on food-contact surfaces. SPSS version 27 was used to compute the frequency and percentages. Results demonstrate that the majority of respondents exhibited exemplary hygienic practices, with 50% regularly washing hands during meal preparations and 92.5% recognizing the importance of a clean workspace. All participants (100%) utilized protective gloves and were more cognizant of the hazards of handling food without them. In terms of food safety awareness, Mzumbe University led with a mean score of 92.80±7.495, reflecting strong food safety knowledge, while Jordan University had the lowest mean of 68.40±5.15, indicating notable gaps in training and practices. Surprisingly, Mzumbe University restaurants exhibited the highest level of microbiological contamination, with spoons and plates demonstrating Total Viable Count values of 4.75 and 4.61 $\log_{10}$CFU/ml, respectively, despite a superior score in food safety knowledge that was obtained. Total coliform contamination on food surfaces was detected in various campus restaurants, with levels ranging from 2.81 to 3.79 $\log_{10}$CFU/ml, highlighting the necessity for enhanced sanitation measures. To enhance food safety in university restaurants, comprehensive training for food service staff on hygiene and food safety is essential. Implementing routine microbial monitoring, strict cleaning protocols, and regular safety audits can significantly reduce foodborne illness risks and ensure a safe dining environment for patrons.

Keywords

Food Safety, Microbial Contamination, University Restaurants, Food Service Workers, Foodborne Illnesses

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1. Introduction

Food safety is a critical public health concern that is inextricably linked to food handling, preparation, and storage [10]. The global burden of foodborne illnesses is staggering, with 600 million cases of food illnesses and 420,000 deaths, resulting in significant morbidity and mortality. Studies have consistently demonstrated a correlation between foodborne outbreaks and the food service sector, particularly in developing countries [3, 18, 21, 24]. A primary cause of foodborne diseases is the contamination of food by microorganisms, including bacteria, viruses, and parasites. Common pathogens implicated in foodborne outbreaks include *Salmonella*, *Escherichia coli*, *Staphylococcus aureus*, *Bacillus cereus*, *Vibrio* species, rotaviruses, noroviruses, and *Cyclospora* [16]. The symptoms of foodborne illnesses vary widely but often include gastrointestinal distress, fever, and in severe cases, death. Developing countries, such as Tanzania, bear a disproportionate burden of foodborne illnesses due to factors such as inadequate food handling practices, limited food safety awareness, and insufficient regulatory frameworks. These factors create a conducive environment for the proliferation of foodborne pathogens. Food-contact surfaces (FCS) play a pivotal role in food safety. These surfaces, including food preparation tables, cutting boards, utensils, and equipment, can harbor pathogenic microorganisms that contaminate food, leading to outbreaks. Inadequate cleaning and disinfection practices can contribute to the persistence of these pathogens, increasing the risk of cross-contamination. University restaurants, often serving large and diverse populations, face unique challenges in ensuring food safety. The complexity of managing food safety protocols in these environments necessitates a comprehensive understanding of the microbial status of FCS. This knowledge is essential for identifying potential risks and implementing effective control measures. The knowledge and practices of food handlers in university settings are critical determinants of food safety. Previous studies have highlighted deficiencies in food safety knowledge among food handlers, including inadequate understanding of key concepts such as handwashing, temperature control, and cross-contamination prevention. These deficiencies can lead to errors in food handling practices, increasing the risk of foodborne illnesses. This study evaluated the food safety knowledge of food service workers and the microbial status of food-contact surfaces in university restaurants in Morogoro, Tanzania, aiming to identify gaps in food safety practices and inform targeted interventions. By assessing workers' knowledge, analyzing microbial contamination, and examining the relationship between these factors, the study seeks to uncover influential elements affecting food safety and provide actionable insights for improvement. The findings will support the development of tailored training programs, enhance regulatory oversight, and promote effective food safety practices in university settings. Furthermore, the research contributes to the broader understanding of food safety challenges in developing countries, offering valuable evidence to inform policies and interventions aimed at reducing foodborne outbreaks and protecting public health.

2. Materials and Methods

2.1. Research Design and Sampling

A cross-sectional study was conducted between February and June 2024 to assess the food safety knowledge (FSK) of food handlers (FHs) and the microbiological status of food-contact surfaces in university restaurants in Morogoro. A total of 40 food service employees responsible for preparing, cooking, and serving meals to customers at a specific university in Morogoro participated in the study. Eighty (80) swab samples from food-contact surfaces were obtained from four universities (MZUMBE, SUA, MUM, and JORDAN) in Morogoro Municipality, with one restaurant purposively selected from each university. Sample of swabs conveniently collected from food-contact surfaces were dispatched to the laboratory at the department of Agro-processing, Sokoine University of Agriculture for microbiological analysis.

2.2. Data Collection Methods

Data were collected from the study area through a combination of questionnaires, observations, and microbial analyses.

2.2.1. Questionnaire

Data on food safety knowledge among food service workers were collected using well-structured questionnaires translated and administered in Swahili. The questionnaire comprised two sections: the first gathered demographic information, including gender, age, educational level, and duration of employment. The second section assessed food safety knowledge, training, handling practices, and awareness of microorganisms that cause foodborne illness. Forty restaurant service workers who volunteered to participate in the study completed the questionnaires. Those who declined to participate were excluded. Questionnaires were distributed to each participant to maintain privacy and anonymity.

2.2.2. Observation

A direct observation approach was employed to gather data on nonverbal behaviors related to hygienic practices and environmental conditions. Specifically, the observations focused on food handling practices, personal hygiene of food service workers, and the state of food-contact surfaces. A structured observation checklist served as a framework for data collection. The checklist was designed from good manufacturing practices and good hygienic practices requirements

by reviewing the literature.

2.3. Microbial Analysis

Microbial analysis was conducted to determine the total viable count (TVC) and total coliform count (TCC) of food-contact surfaces in university restaurants. Samples were collected from serving plates, food preparation tables, food slicers, and spoons using sterile collection swabs moistened with sterile peptone salt solution. Swabbing was performed using a rotational protocol, with five samples taken randomly from each category of food-contact surface in every selected university restaurant. After swabbing, the swabs were placed in labeled tubes and stored at 8°C for two hours before being transported to the laboratory at the department of Agro-processing laboratory, Sokoine University of Agriculture. Upon arrival, both TVC and TCC were determined according to ISO standard microbiological techniques.

2.3.1. Microbial Load by Total Viable Count (TVC)

To assess the level of microbial contamination, colony-forming units (CFUs) were enumerated. Swab samples were collected from food-contact surfaces and mixed with sterile normal saline. The resulting suspensions were serially diluted tenfold, and 1 mL of each dilution was plated onto nutrient agar Petri dishes. After incubation at 37°C for 24 hours, colonies were counted to determine the CFU/ml The mean total viable count (TVC) values for each food-contact surface were subsequently calculated and tabulated using a formula;

$$\text{No. of bacteria in } \left(\frac{\text{CFU}}{\text{ml}}\right) = \frac{\text{number of colonies x reciprocal of dilution factor}}{\text{inocilum size (ml)}} \quad (1)$$

2.3.2. Microbial Load by Total Coliform Count (TCC)

Total coliform counts were measured using MacConkey agar media. Each sample underwent five successive serial dilutions (10^{-1}, 10^{-2}, 10^{-3}, $10^{-4,}$ and 10^{-5}). From each dilution, 1 ml was transferred to sterile Petri dishes that contained about 15 ml of solidified MacConkey agar. These were incubated at 37°C for 24 hours. Colony counting was performed after the incubation period. The colony-forming units per gram (CFU/ml) were calculated according to equation (1).

2.4. Data Analysis

Data were gathered and organized in Microsoft Excel. Subsequent analysis was performed using the Statistical Package for Social Sciences (SPSS) Version 20. Descriptive statistics, comprising frequencies and percentages for food safety knowledge, were calculated for categorical data, while means and standard deviations were derived. The microbial status data (TVC and TCC) were compiled in a spreadsheet, calculating the average and standard deviation of $\log_{10}$ CFU/ml for each food contact surface from all University restaurants. The mean values were later employed to compare contamination levels across different university restaurants.

3. Results

3.1. Distribution of Sociodemographic Characteristics of Respondents

Demographic characteristics of food service workers are presented in Table 1. The majority of participants (72.5%) were female, with a significant proportion (50%) aged 18-24. A substantial number (30%) were in the 25-34 age range, while 15% were aged 35-44. In terms of education, 52.5% possessed secondary education, followed by 22.5% with primary education and 22.5% with diploma education. A smaller percentage (2.5%) held university degrees. Regarding work experience, 30% of food service workers had 1-2 years of experience, 35% had 3-4 years, and 17.5% had either less than a year or more than five years of experience.

Table 1. Demographic information of foodservice workers.

Parameters	Answer choice	Percentage
Age of a respondent	18-24	50.0
	25-34	30.0
	35-44	15.0
	45 or older	5.0
Gender of a respondent	Male	27.5
	Female	72.5
Level of education of a respondent	Primary education	22.5
	Secondary education	52.5
	Diploma	22.5
	Degree	2.5
Number of years working as a food handler	Less than one year	17.5
	1-2 years	30.0
	3-4 years	35.0
	More than 5 years	17.5
Current position at the University cafeteria	Manager	10.0
	Chef	22.5
	Food preparation staff	47.5

Parameters	Answer choice	Percentage
	Server	20.0

3.2. Food Safety Knowledge and Practices of the Food Service Workers

Table 2 summarizes the results regarding food safety knowledge and practices among food service workers. A survey of food service workers revealed a high level of awareness regarding essential food safety practices. Ninety-seven percent accurately identified the ideal storage temperature for perishable foods, while the majority (70%) understood the importance of using separate chopping boards and utensils for raw and cooked items. However, despite this knowledge, only 30% consistently wore gloves when handling ready-to-eat food. Despite the widespread awareness of the need to wash raw produce before consumption, a significant proportion (67.5%) of respondents were observed to unhygienically handle food and food contact surfaces. Moreover, 97.5% utilized different cleaning agents for various surfaces, demonstrating a commitment to maintaining a sanitary environment. While all food service workers reported receiving training on proper food handling techniques, 12.5% indicated having never participated in food safety training. Furthermore, the frequency of training varied, with 57.5% receiving monthly instruction, 12.5% every six months, and 17.5% less frequently.

A questionnaire assessed the knowledge of food service workers regarding food handling practices. Respondents demonstrated a strong commitment to food safety protocols and education. The majority exhibited exemplary hygiene practices, with 50% regularly washing hands during meal preparation and 92.5% recognizing the importance of a clean workspace and early-shift handwashing. However, only 30% had received formal instruction on proper sanitation techniques. All participants (100%) utilized protective gloves and were cognizant of the hazards of handling food without them. Moreover, all agreed on the necessity of sanitizing food-contact surfaces and using designated utensils for different food types. Despite a high awareness of contamination risks, a significant practice gap persisted, with 62.5% of staff allowing raw food to come into contact with cooked or dried products.

Table 2. *Food safety knowledge and practices among food service workers.*

Parameters	Answer choice	Percentage (%)
The time interval for receiving food safety training	Monthly	57.5
	Every six month	12.5
	Once a year or less often	17.5
	Never received training	12.5
Principles that a respondent received training on	Proper handwashing techniques	25.0
	Food storage and temperature control	47.5
	Preventing cross-contamination	20.0
	Preventing cross-contamination	7.5
Familiar with handwashing techniques	Yes	100
	No	0
Received training on proper food handling techniques	Yes	100
	No	0
Knowledge correct temperature for storing perishable food	Yes	97.5
	No	2.5
Understanding the importance of using separate cutting boards for raw meat and produce	Yes	70
	No	30
Separate utensils for handling raw and cooked foods	Yes	100
	No	00
Are gloves worn when handling ready-to-eat food	Yes	30

Parameters	Answer choice	Percentage (%)
Washing fruits or vegetables before use	No	70
	Yes	100
Witnessed any contamination in the food contact surface	No	00
	Yes	67.5
	No	32.5
Frequency of cleaning and sanitizing food contact surface	Daily	100
	Weekly	00
	Monthly	00
	Occasionally	00
	Never	00
Different cleaning materials for different contact surfaces	Yes	97.5
	No	2.5

Parameters	Answer choice	Percentage
Received training on proper sanitation procedure	Yes	30
	No	70
Often wash hands during food preparation and handling	Frequently	50.0
	Once a day	15.0
	more often	35.0
Procedures for reporting foodborne illnesses	Yes	65.0
	No	35.0
Often wash hands while handling food	Frequently	42.5
	more often	57.5
Procedures for reporting foodborne illnesses	Yes	65
	No	35
The work area should be organized before starting work	Yes	92.5
	No	7.5
Washing hands early in the shift reduces the risk of external contamination	Yes	92.5
	No	7.5
Contamination caused by several types of hazards	Yes	92.5
	No	7.5
Using protective gloves when handling food reduces the chances of food contamination	Yes	100
	No	00
Personal hygiene can prevent food contamination and make it safer	Yes	100
	No	00
Health hazards by scooping or serving food with ungloved	Yes	97.5
	No	2.5
Use of protective measures to cover mouth when coughing or sneezing	Yes	100

Parameters	Answer choice	Percentage
Handlers with wounds or illness/infection symptoms should not engage in these activities	No	00
	Yes	97.5
A clean work environment is crucial for preventing food contamination	No	2.5
	Yes	95
	No	5
Parameters		
Sanitizing all food contact surfaces with water and soap before using a sanitizer	Yes	100
	No	00
Usage of separate plates and utensils for processing different types of food is important	Yes	100
	No	00
Washing a knife used to cut meat with water or a sanitizer before use is essential	Yes	100
	No	0.00
Cleaning food contact surface daily with water and sanitizer	Yes	100
	No	0.00
Raw food can come into contact with cooked/dry food	Yes	62.5
	No	37.5

3.3. Awareness of Microorganisms That Cause Foodborne Illness

The awareness of microorganisms implicated in foodborne illness among food service workers is summarized in Table 3. While a majority (67.5%) recognized the potential for severe, even fatal, outcomes from bacterial contamination, significant disparities existed in knowledge of specific pathogens. *Salmonella* was the most widely recognized (75%), followed by *Escherichia coli* (30%), while *Clostridium* and *Staphylococcus* were less familiar (27.5%). Only 12.5% had undergone formal food safety training, and a substantial 85% deemed current training inadequate. Nevertheless, 95% of employees expressed a need for more comprehensive instruction in various food safety aspects.

Table 3. *Awareness of microorganisms that cause foodborne illness.*

Parameters	Yes (%)	No (%)
Some germs can cause foodborne illnesses that can lead to death	67.5	32.5
Heard of Salmonella	75.0	25.0
Heard of Escherichia Coli	30.0	70.0
Heard of Clostridium	27.5	72.5
Heard of Staphylococcus	27.5	72.5
Received formal training in food safety	12.5	87.5
Are current training methods effective?	15.0	85.0
Presence of specific areas of food safety you feel need more training	95.0	5.0

3.4. Comparison of Food Safety Knowledge Between Restaurants from Different Universities

A comparative analysis of food safety knowledge among food service professionals at MZUMBE, SUA, MUM, and JORDAN Universities revealed significant performance discrepancies (Table 4). Mzumbe University exhibited the highest level of proficiency, achieving 100% correct responses to critical questions about handwashing frequency and protective glove utilization. SUA demonstrated comparable competence, particularly in reporting foodborne illnesses (90%) and employing separate utensils (90%) although their knowledge varied across other domains. Mum's performance was commendable with a mean score of (76.40±3.978) (Table 5), with notable strengths in understanding optimal storage temperatures (70%) and handwashing frequency, but weaknesses in surface sanitization (60%). Jordan University exhibited the lowest overall knowledge with a mean score of (68.40±5.147) (Table 5), particularly regarding the necessity of utilizing separate cutting boards (60%) and reporting protocols for foodborne diseases (60%). This disparity underscores the urgent need for targeted food safety training at these institutions.

Table 4. Comparison of food safety knowledge of food service workers between one.

Questions regarding food safety knowledge	Correct responses			
	Mzumbe n (%)	SUA n (%)	MUM n (%)	JORDAN n (%)
	9 (90)	8(80)	8(80)	7(70)
Received training on proper food handling techniques	10 (100)	9(90)	7(70)	6(60)
Knowledge of the correct temperature for storing perishable food	8 (80)	8(80)	7(70)	7(70)
Understanding the importance of using separate cutting boards for raw meat and produce	9 (90)	7(70)	8(80)	6(60)
Separate utensils for handling raw and cooked foods	9(90)	9(90)	7(70)	8(80)
Washing fruits or vegetables before use	10(100)	8(80)	8(80)	7(70)
Frequency of cleaning and sanitizing food contact surface	8 (80)	8(80)	6(60)	7(70)
Use of different cleaning materials for different contact surfaces	9 (90)	7(70)	7(70)	6(60)
Frequency of washing hands during food preparation and handling	9 (90)	8(80)	8(80)	7(70)
Understanding of Procedures for reporting food borne illnesses	9 (90)	9(90)	8(80)	6(60)
Frequency of washing hands while handling food	10 (100)	8(80)	7(70)	7(70)
Can swollen cans contain microorganisms	8 (80)	7(70)	6(60)	8(80)
The work area should be organized before starting work	9 (90)	8(80)	7(70)	6(60)
Washing hands early in the shift reduces the risk of external contamination	9 (90)	9(90)	8(80)	7(70)
Using protective gloves when handling food reduces the chances of food contamination	10 (100)	8(80)	7(70)	6(60)
Handlers with wounds or illness/infection symptoms should not engage in these activities	8 (80)	7(70)	7(70)	8(80)
Washing all food contact surfaces with water and soap before using a sanitizer	9 (90)	8(80)	6(60)	7(70)
Bacteria can be found on the skin and nose of healthy individuals	8 (80)	9(90)	8(80)	6(60)
Washing a knife used to cut meat with water or a sanitizer before use is essential	9 (90)	7(70)	8(80)	7(70)
Bloody diarrhea can be transmitted by food	9 (90)	8(80)	7(70)	6(60)

Questions regarding food safety knowledge	Correct responses			
	Mzumbe n (%)	SUA n (%)	MUM n (%)	JORDAN n (%)
Raw food can come into contact with cooked/dry food	9 (90)	7(70)	8(80)	7(70)
Who is responsible for food safety	8 (80)	9(90)	7(70)	6(60)
What do you do with leftovers	9 (90)	8(80)	7(70)	7(70)

3.5. Food Safety Knowledge Score in University Restaurants Workers

Table 5. Food safety knowledge score in university restaurants workers.

University Restaurant	Knowledge means score±STDev
MZUMBE	92.80±7.495
SUA	85.60±9.082
MUM	76.40±3.978
JORDAN	68.40±5.147

SUA: Sokoine University of Agriculture, MUM: Muslim University of Morogoro, JORDAN: Jordan University, MZUMBE: Mzumbe University

Table 5 presents the food safety knowledge scores of university restaurant workers in Morogoro. Mzumbe University demonstrated the highest mean score of 92.80±7.495, indicating a robust understanding of food safety principles. SUA University followed with a mean score of 85.60±9.082, suggesting a satisfactory level of knowledge but with room for refinement. MUM University and JORDAN University scored significantly lower, at 76.40±3.978 and 68.40±5.147 respectively, highlighting deficiencies in their training and practices. These findings underscore the imperative for targeted interventions to enhance food safety education and training at MUM and JORDAN Universities.

3.6. Observation Checklist for Food Safety and Hygienic Practices

A comprehensive assessment of food safety practices in university restaurants revealed a variable level of compliance as shown in Table 6. Despite a majority of food service workers (75%) demonstrating appropriate hand hygiene and attire, adherence to these practices was inconsistent. Only 12.5% of workers consistently avoided touching their body parts during food preparation. While 75% of restaurants maintained separate storage for raw and cooked food and utilized distinct utensils, a significant number (75%) failed to maintain a clean and organized preparation area. Furthermore, although 75% of restaurants had adequate handwashing facilities, only 62.5% of employees consistently used food covers to prevent contamination. Proper waste disposal was evident in 75% of establishments, yet overall adherence to food safety standards remained low, with only 12.5% of restaurants demonstrating comprehensive compliance.

Table 6. Observation Checklist observed in selected University restaurants.

Criteria	Yes (%)	No (%)
Staff wash their hands with soap and water before handling food	75	25
Staff wear clean and appropriate attire during food preparation	75	25
Staff avoid touching their body parts while preparing foods	12.5	87.5
Staff use separate cutting boards and knives for raw and cooked meat	75	25
Staff store raw and cooked food separately	75	25
The preparation area for food is clean and well-maintained	25	75
Staff use food coverings to protect against contamination	62.5	37.5
Handwashing facilities are adequately equipped with soap and water	75.0	25.0

Criteria	Yes (%)	No (%)
Staff wash and sanitize all kitchen utensils and equipment after use	62.5	37.5
Waste is disposed of properly and bins are covered	75	25
Staffs adheres to principles of food safety during food handling	12.5	87.5
Staff report or refrain from handling food if sick	37.5	62.5
Staff practice proper coughing or sneezing etiquette	50	50
Food contact surfaces are cleaned and sanitized before and after use	62.5	37.5
Cross-contamination is avoided by using gloves or utensils when handling ready-to-eat foods	25.0	75.0
Cleaning procedures are followed according to the guidelines	12.5	87.5
Food service workers can't have long nails and make coloring them	87.5	12.5

3.7. Microbial Status of Food Contact Surface Results

Table 7 presents the microbial status of food contact surfaces in four university restaurants in Morogoro. Total viable counts (TVC) and TCC varied significantly among the establishments. Mzumbe University restaurants exhibited the highest levels of microbial contamination, with spoons and plates harboring TVC of 4.75 ± 0.94 and 4.61 ± 0.71 log_{10} CFU/ml, respectively. While TCC were lower, they remained elevated compared to the other restaurants. Jordan University restaurants also demonstrated high TVC levels, particularly on tables (2.79±1.09 log_{10}CFU/ml) and slicers (3.32±0.92 CFU/ml). However, TCC was consistently lower than TVC throughout. At SUA restaurants, TVC microbial contamination was moderate on most surfaces, with spoons (4.48±0.77 log_{10}CFU/ml) and plates (4.30± 1.00 log_{10}CFU/ml) showing the highest counts. The MUM restaurants exhibited substantial TVC contamination, especially on tables (5.91±0.92 log_{10}CFU/ml).

Table 7. Microbial status of the food contact surfaces in log10CFU/ml.

Restaurant location	FCS	TVC (log_{10}CFU/ml) Mean ± STDev	TCC (log_{10}CFU/ml) Mean ± STDev
MZUMBE	Spoon	4.75±0.94	2.42±0.61
	Table	2.83±0.37	2.34±0.92
	Slicer	2.41±0.10	2.11±0.20
	Plate	4.61±0.719	2.78±0.57
JORDAN	Spoon	4.32±0.89	1.96±0.23
	Table	7.13±0.91	2.79±1.09
	Slicer	6.50±1.40	3.32±0.92
	Plate	6.31±0.91	2.75±0.63
SUA	Spoon	4.48±0.77	1.97±0.38
	Table	4.15±1.01	2.18±0.13
	Slicer	3.94±0.69	2.03±0.30
	Plate	4.30± 1.00	2.15±0.34
MUM	Spoon	5.04±0.60	2.16±0.22
	Table	5.91±0.92	3.02±0.69

Restaurant location	FCS	TVC (log_{10}CFU/ml) Mean ± STDev	TCC (log_{10}CFU/ml) Mean ± STDev
	Slicer	5.23±1.20	2.35±0.18
	Plate	4.33±0.47	3.46±1.20

TVC: Total Viable Count, TCC: Total Coliform Count, FCS: Food Contact Surfaces, CFU- Coliform Forming Units, SUA: Sokoine University of Agriculture & MUM: Muslim University of Morogoro

The mean total viable count (TVC) values (CFU/ml) of food contact surfaces (spoon, table, slicer, and plate) among four university restaurants (MZUMBE, JORDAN, SUA, and MUM) are illustrated in Figure 1. The data shows that Jordan University restaurants consistently had the highest TVC contamination, particularly on tables and slicers, indicating higher microbial contamination compared to the other universities. MZUMBE and SUA universities generally show lower TVC values, suggesting better hygiene practices or more effective cleaning. For specific surfaces, MZUMBE has the lowest mean TVC for spoons and slicers, while Jordan has the highest contamination levels on tables and slicers. The contamination levels at MUM's restaurant were was reported to be higher for spoons and slicers, although comparable to those at SUA and MZUMBE for plates. The variation in TVC contamination among food contact surfaces indicates variations in cleaning and hygiene protocols at each university. The findings indicate that Jordan's restaurant necessitates improvements in cleanliness, particularly on frequently utilized surfaces such as tables and slicers. MZUMBE and SUA exhibit superior hygiene standards, characterized by reduced microbial contamination levels. Prioritize regular cleaning and monitoring to assure food safety and reduce contamination risks at all locations.

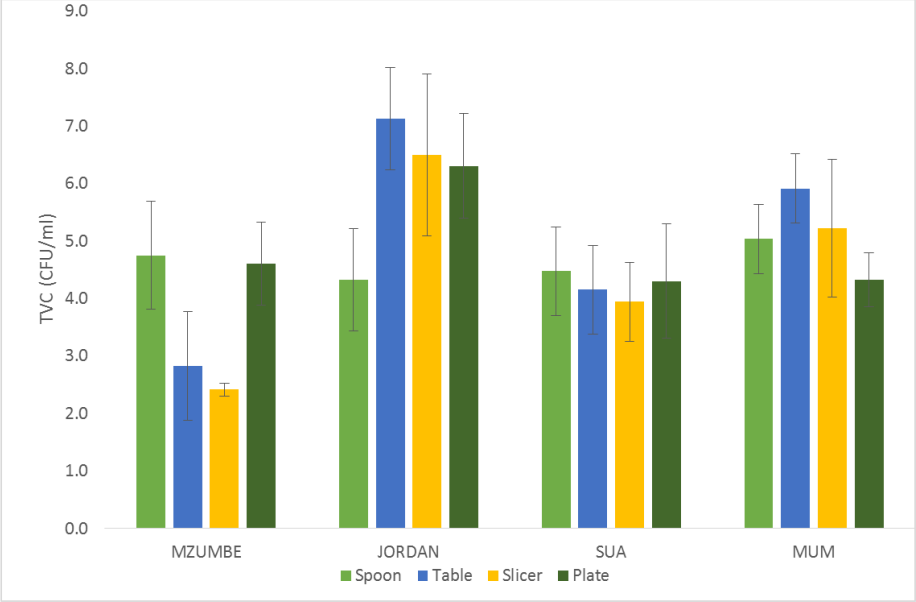

Figure 1. *Mean total viable count (TVC) of food contact surfaces in respective University restaurants.*

The mean total coliform count (TCC) values (CFU/ml) for food contact surfaces (spoon, table, slicer, and plate) across four university restaurants (MZUMBE, JORDAN, SUA, and MUM) are presented in Figure 1. Figure 2 depicts total coliform count (TCC) values for four food contact surfaces (Spoon, Table, Slicer, and Plate) in the university restaurants at Mzumbe, Jordan, SUA, and MUM. Mzumbe and SUA university restaurants generally exhibited lower TCC values, suggesting better hygiene practices, while restaurants at Jordan and MUM showed higher contamination on certain surfaces, particularly tables and slicers. Spoons show almost similar TCC contamination across the universities, with Mzumbe having the highest at 2.42. Tables at Jordan and MUM universities have higher TCC values (2.81 and 2.96 log_{10}CFU/ml), respectively), indicating potential cleaning issues. Slicers show the most variation, with Jordan having

the highest contamination at 3.29 log_{10}CFU/ml, while MUM, SUA, and MZUMBE University restaurants have lower values, pointing to possible unhygienic concerns with cleaning at Jordan. Plates displayed significant differences in TCC values, with MUM university restaurants having the highest TCC contamination at 3.79 log_{10}CFU/ml, which suggests the need for better cleaning practices. Overall, the higher TCC contamination levels in Jordan and MUM universities underscore areas where hygiene standards could be improved, especially with slicers and plates. Implementing more thorough cleaning and regular monitoring is necessary to enhance food safety in these locations.

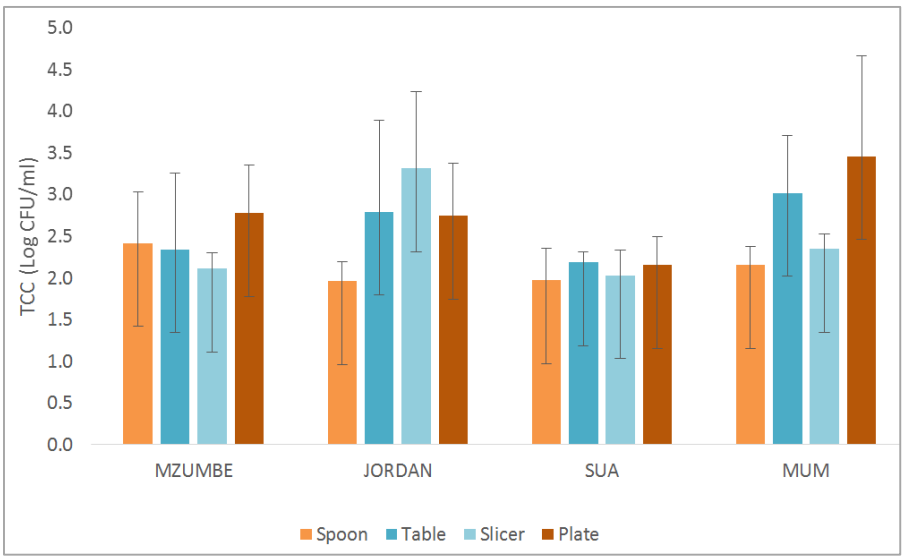

Figure 2. *Mean total coliform count (TCC) of food contact surfaces in respective University restaurants.*

4. Discussion

An assessment of food safety knowledge and microbial contamination on food contact surfaces in Morogoro University restaurants offers valuable insights into the prevailing state of food safety practices within these establishments. This section summarizes the study's key findings, situates them within the broader context of existing literature, and proposes essential recommendations for targeted food safety interventions.

4.1. Demographic Information Among Food Service Workers

This study revealed that 50% of food service workers aged 18-24, a predominantly youthful demographic, lack significant experience or specialized training in food safety. This aligns with those of [12] findings of a low percentage of older employees, suggesting a dearth of experienced mentorship crucial for maintaining stringent food safety protocols. The gender disparity in the study, with 72.5% female respondents, mirrors industry trends. While this demographic imbalance may influence safety procedures and training, inclusive and effective programs are essential to ensure comprehensive knowledge dissemination [9]. However, possessing food safety knowledge does not always equate to safe practices, as [1] demonstrated. To mitigate these challenges, implementing regular, tailored training programs is crucial. These programs should prioritize practical application, enabling food service workers to effectively translate theoretical knowledge into daily practice [19]. The findings underscore the critical need for comprehensive food safety training, particularly among younger workers and those with limited experience. The gender disparity highlights the importance of inclusive training programs that address the unique needs and perspectives of diverse workforces. Additionally, the study emphasizes the gap between theoretical knowledge and practical application, suggesting a need for training that focuses on real-world scenarios and hands-on experience.

4.2. Food Safety Knowledge Among Food Service Workers at The Assessed University Restaurants

The present study reveals a dichotomy in food service workers' adherence to food safety protocols: whereby generally high, notable gaps persist. These findings resonate with [11]'s statement that 70% of individuals lack formal sanitation training, a concerning omission given training's pivotal role in reinforcing food safety knowledge and practices. Despite the CDC's clear hand hygiene guidelines, [22] report inconsistent adherence, with 50% of individuals washing their hands more frequently than others. This variability in hand-washing practices, as documented by [6],

underscores the need to enhance knowledge among the remaining 35% of individuals, even as 65% demonstrate awareness of foodborne disease reporting protocols [23]. The literature supports the importance of protective measures and a clean work environment in preventing contamination, as evidenced by the high degree of consensus on these matters [5]. Furthermore, [17] research highlights the inevitable introduction of bacteria, particularly *Staphylococcus aureus*, by food handlers through actions such as nose-wiping, sneezing over food, scratching the skin, and handling food with bare hands. The data presented highlight the need for ongoing education and training initiatives to address the identified gaps in food safety knowledge and practices. These initiatives should emphasize the importance of proper hand hygiene, the use of personal protective equipment, and the maintenance of a clean and sanitized food preparation environment. Additionally, the study findings show the potential for cross-contamination from food handlers. This reinforces the need for strict adherence to food safety practices, such as avoiding contact between raw and cooked foods and regularly sanitizing equipment and surfaces. By addressing these issues, food service establishments can significantly reduce the risk of foodborne illness and protect the health of consumers. The present study further highlighted deficiencies in food service workers knowledge of certain hygienic topics, temperature control, and the consequences of foodborne pathogens. These findings support [2] assertion that inadequate training and knowledge gaps among food handlers pose significant food safety risks. The assessment of food safety knowledge and microbial status in university restaurants in Morogoro, Tanzania, identified significant disparities among institutions. MZUMBE University restaurants demonstrated a superior understanding of key food safety principles, as evidenced by a significantly higher mean score (92.80±7.495) compared to SUA (85.60±9.082), MUM (76.40±3.978), and JORDAN (68.40±5.147). This superiority was particularly evident in areas such as proper food handling, hand hygiene, and the use of protective gear [20]. Conversely, JORDAN University restaurants exhibited the lowest knowledge scores, suggesting potential deficiencies in food safety practices. Inadequate adherence to cleaning and sanitizing protocols could contribute to increased microbial contamination on food contact surfaces. These findings underscore the critical need for targeted interventions to enhance food safety knowledge and practices in university restaurants, particularly in institutions with lower scores. The results underscore the pivotal role of effective food safety training in fostering knowledge and practices. Institutions with higher knowledge scores, such as Mzumbe, likely benefit from more comprehensive training programs, contributing to enhanced hygiene and reduced microbial contamination. In contrast, Jordan's lower knowledge levels highlight the urgent need for improved training and implementation of food safety practices to mitigate contamination risks [4].

4.3. Awareness of Microorganisms That Cause Foodborne Illness

The present study also reveals critical gaps in respondents' knowledge of microorganisms that cause foodborne illness, highlighting the need for improved training and education. While a majority (67.5%) recognize the lethal potential of foodborne pathogens, a significant minority (32.5%) remain unaware, underscoring the severity of the issue. Awareness of specific microorganisms varies markedly. While *Salmonella* is widely recognized, knowledge of *Escherichia coli*, *Clostridium*, and *Staphylococcus* is significantly lower. To enhance food safety, comprehensive training encompassing a broader range of microorganisms is essential. Moreover, the study reveals deficiencies in formal training and its perceived effectiveness. A substantial majority (87.5%) of respondents lack formal training, and only 15% of those who have received training find it effective. This calls for a rethinking of training programs to make sure they are interesting, useful, and include hands-on exercises to help participants learn and remember more. Keeping one's knowledge and skills up-to-date is another benefit of regular training and refresher courses [15].

4.4. Observed Behaviors and Hygiene Practices of University Restaurants' Food Handlers

The observations checklist from the study on food safety practices in university restaurants indicated a diverse adherence to essential hygiene and safety protocols (Table 6). While a majority of staff (75%) consistently washed their hands and wore appropriate attire, a significant proportion exhibited suboptimal personal hygiene practices, such as touching body parts during food preparation. This gap in personal hygiene increases the risk of food contamination and underscores the need for enhanced training and stricter adherence to personal hygiene standards, as highlighted by [7]. While food handling practices demonstrated some positive aspects, such as the use of isolated cutting boards and knives for raw and cooked meats, the effectiveness of preventing cross-contamination was compromised by the inadequate use of gloves or utensils for ready-to-eat foods and the failure to adhere to cleaning procedures. Furthermore, the cleanliness of food preparation areas was suboptimal, suggesting a critical need for enhanced cleaning practices and better adherence to food safety protocols, as emphasized by [13]. Despite adequate hand washing facilities, a significant portion of respondents reported receiving either no formal training or ineffective training. These findings highlight the urgent need for more comprehensive training programs and stricter enforcement of food safety practices to ensure that all staff members follow protocols effectively, as suggested by [14].

4.5. Microbial Status of Food Contact Surfaces

An assessment of microbial contamination on food contact surfaces (FCS) in the university restaurants revealed significant disparities in hygiene practices and microbial load. Notably, Jordan University restaurants exhibited the highest levels of both TVC and TCC, indicating a critical need for improved sanitation protocols. Jordan University restaurant's FCS, particularly slicers and plates, harbored substantially higher levels of TVC and TCC compared to other institutions. These findings suggest potential deficiencies in cleaning practices or the presence of microbial reservoirs within their food service operations. While Mzumbe University restaurants and the MUM restaurants also demonstrated elevated TVC levels on certain FCS, their overall microbial contamination was less severe. The presence of coliforms, indicative of potential fecal contamination, was most pronounced at Jordan University, particularly on slicers and plates. This underscores the importance of stringent cleaning procedures to prevent cross-contamination and mitigate the risk of foodborne illness. In contrast, SUA restaurants exhibited lower TCC values, suggesting more effective sanitation practices. These results underline the necessity for rigorous hygiene monitoring and implementation of effective cleaning protocols to minimize microbial contamination risks in university restaurants. While SUA's lower contamination levels demonstrate the feasibility of achieving acceptable hygiene standards, institutions like JORDAN University and MUM must address their higher contamination levels to protect public health. To mitigate these risks, it is imperative to implement rigorous cleaning schedules and routine monitoring programs for microbial loads on FCS. This includes the use of appropriate cleaning agents, effective cleaning techniques, and regular disinfection of high-risk areas. Additionally, staff training on proper hygiene practices is essential to ensure consistent adherence to sanitation protocols. A prior study determined that a standardized set of sanitary operating procedures, akin to those employed by the food and food service industries, should be established to aid the center's food staff in the efficient cleaning and sanitizing of surfaces to mitigate potential hazards [8]. Comparing the TCC across the different items and locations reveals some patterns. For example, the mean TCC values for the spoon are relatively consistent across all locations, ranging from 2.11 to 2.42. However, for the table and plate, the mean TCC values show more variation between locations, indicating potential differences in contamination levels or cleaning practices. Overall, the findings highlighted differences in coliform contamination across various items and locations, with some locations indicated higher contamination and variability than others. Understanding these patterns can help in identifying areas that require improved sanitation practices to reduce coliform contamination.

5. Conclusion and Recommendations

These findings reveal a significant microbial burden on food contact surfaces, indicating a critical deficit in food safety knowledge and practices within the studied institutions. The prevalence of microbial contamination underscores the urgent need for comprehensive training programs to educate food service workers and high school students about proper food handling techniques. By enhancing awareness and implementing standardized operating procedures (SOPs) for cleaning, routine microbial monitoring, and regular audits, we can effectively mitigate risks and promote healthier dining environments for both Tanzanian and foreign university populations.

Abbreviations

FCS	Food Contact Surfaces
TVC	Total Viable Count
TCC	Total Coliform Count
SUA	Sokoine University of Agriculture
CFU	Total Coliform Count
FSK	Food Safety Knowledge

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Author Contributions

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The authors declare that they have all the necessary data and are available where appropriate or requested by the editor.

Conflicts of Interest

The authors declare no competing interest.

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