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Evaluation of the Contamination Rate of Several Foodborne Pathogenic Bacteria in Street-Vended Beverages Collected in Ea Kao Commune, Dak Lak Province

Trinh Thi Huyen Trang[1], Ho Thi Hao*[2],
[1]Faculty of Natural Sciences and Technology, Tay Nguyen University, Vietnam
[2]Faculty of Agriculture, Tay Nguyen University, Vietnam

Abstract: This study evaluated microbial contamination in selected street-vended beverages collected in Ea Kao Commune, Dak Lak Province, Vietnam. Total aerobic bacterial count, Coliforms, Escherichia coli, and Staphylococcus aureus were analyzed to assess food safety risks. The results showed that most samples exceeded the acceptable microbiological limits. Coliforms were detected in 100% of pennywort juice samples and 13.33% of peach tea samples, whereas no contamination was found in passion fruit juice. E. coli was detected only in several pennywort juice samples. S. aureus was identified in 60% of pennywort juice samples and 13.33% of peach tea and passion fruit juice samples, with counts ranging from 73.67×10^3 to 179.67×10^3 CFU/mL, exceeding regulatory standards. Among the tested beverages, non-heat-treated pennywort juice showed the highest microbial contamination level. The findings indicate inadequate hygiene conditions during beverage preparation, handling, and storage, posing potential health risks to consumers. This study provides scientific evidence for improving food safety management and hygiene control of street-vended beverages in the study area.

Keywords: Street food, Coliforms, E. coli, S. aureus, Food safety.

I. Introduction

In recent decades, along with socio-economic development and rapid urbanization, human food consumption demands have undergone significant changes. While the primary goal in the past was to meet basic energy requirements, consumers today are increasingly concerned about the quality, nutritional value, and particularly the safety of food and beverages. Consequently, food safety has become a major public health issue globally. According to the World Health Organization, approximately 600 million people worldwide fall ill each year from consuming unsafe food, resulting in around 420,000 deaths. Most of these cases are associated with the presence of pathogenic microorganisms in food and drinking water [1]. Furthermore, the Food and Agriculture Organization also emphasizes that microbial contamination is one of the leading causes of foodborne illness outbreaks, especially in developing countries where sanitary conditions and food safety control systems remain limited [2].

In this context, street foods and beverages have become an important component of the food supply system in many countries, particularly in urban and developing regions. These products are widely consumed because of their convenience and affordability. Among them, street-vended beverages are especially popular due to their easy accessibility and suitability for daily consumption. However, owing to small-scale vending practices and poor sanitary conditions during preparation and handling, street foods and beverages are highly susceptible to microbial contamination [3]. Numerous studies have shown that these products can contain various pathogenic microorganisms such as *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* spp., and *Bacillus cereus*, along with bacterial hygiene indicators including Coliforms and total aerobic bacterial counts [4], [5]. These microorganisms can cause various foodborne diseases, including diarrhea, intestinal infections, and digestive disorders, and in severe cases, can lead to dangerous complications for human health. According to the Centers for Disease Control and Prevention, pathogenic bacteria in food remain the primary cause of foodborne disease outbreaks globally [6].

In Vietnam, rapid urbanization and population growth have driven the expansion of street-vended beverage businesses. These products are commonly consumed by various demographics, particularly pupils, students, and laborers, as they align with daily habits and economic conditions. However, many domestic studies indicate that the risk of microbial contamination in beverage and food products remains at an alarming level. For instance, a survey in the Central Highlands region recorded that the percentage of bottled water samples contaminated with microorganisms ranged from 50.7% to 56.7%, with common indicators including total Coliforms, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Clostridia*[7]. Another study in Dak Lak

Province during the 2022–2023 period showed that 67.6% of ready-to-use ice samples failed to meet microbiological standards, with the presence of Coliforms (55.9%), *E. coli* (19.1%), and other intestinal bacteria, with contamination rates tending to be higher during the dry season [8]. These results demonstrate that the risk of microbial contamination in local beverage products remains significant and requires continuous research and monitoring.

Ea Kao Commune, Dak Lak Province, is an area with a relatively high population density, concentrating many pupils, students, and laborers migrating from other localities to live and study. The demand for street-vended beverages in this area is high due to the convenience and affordability of these products. However, the rapid increase in small-scale business establishments, coupled with uncoordinated sanitation and food safety control conditions, may elevate the risk of microbial contamination in these products [9]. Although several studies have evaluated the microbiological quality of drinking water in Vietnam, data on the level of microbial contamination in street beverages in the Ea Kao area, Dak Lak Province, remain limited. Driven by this practical context, the study *"Evaluation of the contamination rate of several foodborne pathogenic bacteria in street-vended beverages collected in Ea Kao Commune, Dak Lak Province"* was conducted to determine the prevalence of key pathogenic bacteria in street beverage samples. The research findings will provide scientific evidence for assessing microbial contamination risks in street-vended beverages and support local authorities in developing and implementing effective food safety control measures.

II. Materials And Methods

2.1. Materials

Research targets: Bacterial groups including Total Plate Count (TPC), Coliforms, *Escherichia coli(E. coli*), and *Staphylococcus aureus* (*S. aureus*).

Research materials: Select street-vended beverages, including passion fruit juice, peach tea, and pennywort juice.

Location of implementation: Laboratory of Microbial Technology – Department of Biology, Faculty of Natural Sciences and Technology, Tay Nguyen University.

2.2. Methods

2.2.1. Sample collection allocation

Based on the field survey, a total of 90 beverage samples were collected, including passion fruit juice, peach tea, and pennywort juice. Forty-five samples (15 of each beverage type) were collected between 10:00 AM and 12:00 PM, while the remaining 45 samples (15 of each beverage type) were collected between 4:00 PM and 6:00 PM.

2.2.2. Survey method for sanitary conditions of street beverage vendors

A total of 45 street beverage establishments selling pennywort juice, passion fruit juice, and peach tea in Ea Kao Commune, Dak Lak Province, were included in the study. Owners or vendors at these establishments were directly observed and interviewed using a structured questionnaire to collect information on facility sanitation conditions and the hygiene practices of handlers involved in the preparation and sale of street-vended beverages [10]. The questionnaire was developed based on the template presented in Table 1.

Table 1: Survey questionnaire template

Parameter	**Survey results**	
Location	…………………	
Time	10:00 AM - 12:00 PM	4:00 PM - 6:00 PM
Ambient temperature	$20^oC – 30^oC$	$>30^oC$
Weather	Sunny	Cloudy / Rainy
Protective gear (apron, gloves, mask)	Yes	No
Nail hygiene	Trimmed short, clean	Long, dirty
Covering utensils	Yes	No
Display and processing equipment	On a high table	On a low table
Sanitary waste bins	Closed, sanitary	Open
Sealing equipment	Using a cup-sealing machine	Manual capping by hand

2.2.3. Sampling method

Food samples were collected from markets, schools, hospitals, and densely populated residential areas in Ea Kao Commune, Dak Lak Province. Samples were gathered at noon from 10:00 AM to 12:00 PM via random purchase from vendors and replicated in the afternoon from 4:00 PM to 6:00 PM. The sampler wore gloves and ensured no cross-contamination occurred between samples, or from the sampler's hands, or from non-sterile utensils (washing hands thoroughly with soap and wearing sterile gloves). Approximately 10 mL of each beverage sample was collected for microbiological analysis. Samples were aseptically transferred into sterile sampling bags, appropriately labeled, and transported promptly to the laboratory. Upon receipt, microbiological analyses were conducted immediately to ensure sample integrity. The evaluation of analytical results was based on the maximum permissible limits of microorganisms in food according to Decision No. 46/2007/QD-BYT [11], as presented in Table 2.

Table 2: Regulatory limits for permissible microorganisms in research samples according to Decision No. 46/2007/QD-BYT dated December 19, 2007, by the Minister of Health

Product	**Type of microorganism**	**Microbial limit (in 1 g or 1 mL of food)**
Non-alcoholic beverages	Total Plate Count	10^2
	Coliforms	10
	E. coli	Negative
	S. aureus	Negative

2.2.4. Method for determining microbiological parameters in food samples

Sample preparation method: Homogenize and transfer 10 g of the sample into 90 mL of Saline Peptone Water (SPW), followed by incubation at 37°C for 24–48 hours. Perform decimal dilutions. Each dilution was inoculated onto 3 Petri dishes. The experiments were replicated 3 times for each sample.

Total Plate Count (according to TCVN 4884-1:2015): Inoculate 1 mL of the sample onto Plate Count Agar (PCA) medium, incubate at 30°C for 48–72 hours, count all colonies formed on the medium post-incubation, and calculate the results [12].

Coliforms (according to TCVN 6848:2007): Inoculate 1 mL of the sample into Violet Red Bile Agar (VRB) medium, incubate at 37°Cfor 24 hours. Coliform bacteria form purplish-pink to dark-purple colonies. Colonies are counted and confirmed using Brilliant Green Bile Salt Lactose (BGBL) broth in test tubes containing Durham tubes by observing gas production and turbidity induced by the bacteria [13].

Escherichia coli (according to TCVN 7924-1:2008): Inoculate 1 mL of the sample into TBX medium, incubate at 44°C}$ for 24 hours. *E. coli* bacteria will form typical blue colonies to determine the quantitative results [14].

Staphylococcus aureus (according to TCVN 4830-3:2005): Select test tubes that turn yellow (positive presumptive) to subculture onto Baird-Parker agar medium. If the sample does not turn yellow, it is considered negative for *S. aureus*. Positive samples will be incubated at 37°Cfor approximately 48 hours. Typical colonies are selected and transferred to Tryptic Soy Agar (TSA) to perform the coagulase test [15].

2.2.5. Data analysis method

Statistical data processing was carried out using SPSS 20.0 software for statistical comparison and correlation analysis, with the significance level set at alpha 0.05.

III. Results and Discussion

3.1. Survey on the sanitary status of street beverage vendors in Ea Kao Commune, Dak Lak Province

3.1.1. Survey on environmental temperature affecting street beverage samples collected in Ea Kao Commune

The environmental temperature recorded during the sampling of street-vended beverages in Ea Kao Commune ranged mainly from 20°Cto above 30°C (Table 3). Most beverage samples were collected under environmental temperatures between 20°C and 30°C at both sampling periods during the day.

Table 3: Environmental temperature survey

Evaluated parameter (Sample size n=45)	Time	Temperature Range	Frequency	Percentage
Temperature	10:00 AM - 12:00 PM	20ºC - 30ºC	33	73,33%
		> 30ºC	12	26,67%
	4:00 PM - 6:00 PM	20ºC - 30ºC	38	84,44%
		> 30ºC	7	15,56%

Specifically, during the morning sampling period (10:00–12:00), out of 45 collected samples, 33 samples (73.33%) were obtained when the environmental temperature ranged between 20–30 °C, while 12 samples (26.67%) were collected when the temperature exceeded 30 °C. During the afternoon sampling period (16:00–18:00), the proportion of samples collected within the 20–30 °C range increased to 84.44% (38/45 samples), whereas the proportion of samples collected at temperatures above 30 °C decreased to 15.56% (7/45 samples).

This pattern is likely associated with the climatic characteristics of the Central Highlands region of Vietnam, where temperatures typically peak around midday and gradually decline toward the late afternoon. Although the proportion of samples collected at temperatures above 30 °C was relatively small, the majority of samples were still obtained within a temperature range considered favorable for microbial growth.

Temperature is a critical factor affecting the proliferation of microorganisms in food and beverages. Many foodborne pathogens, including E.coli, Salmonella spp., and Staphylococcus aureus, grow optimally at temperatures between 20 °C and 37 °C. Consequently, beverages prepared and stored at ambient temperature may present an increased risk of microbial contamination if they are held for extended periods before consumption. Similar findings have been reported in studies on street-vended foods and beverages in developing countries, where inadequate temperature control during storage and vending has been identified as a key factor contributing to microbial contamination [3],[5].

In practice, many street-vended beverages such as pennywort juice, passion fruit juice, and fruit-based teas are prepared in advance and displayed at ambient temperature throughout the selling period. Under such conditions, especially in tropical climates, microbial populations may rapidly increase, thereby elevating potential food safety risks for consumers.

To mitigate the impact of environmental temperature on microbial contamination, appropriate storage practices should be applied. Maintaining beverages under refrigerated conditions below 5°C can significantly slow the growth of pathogenic microorganisms, thereby improving the microbiological safety of ready-to-drink products [10]. In addition, the use of insulated containers or portable cooling systems by street vendors may help minimize temperature-related microbial risks during vending.

3.1.2. Survey on hygiene conditions at street beverage establishments in Ea Kao Commune

Sanitation conditions at food and beverage establishments play a major role in ensuring food safety and limiting the risks of microbial contamination. According to the regulations of the Ministry of Health of Vietnam, food service facilities must simultaneously fulfill requirements for infrastructure, equipment, environmental sanitation conditions, and personal hygiene practices of individuals directly processing and serving food to minimize the risk of food contamination [10]. The results of the sanitation condition survey at street beverage establishments in Ea Kao Commune are shown in Table 4.

Table 4: Survey on sanitation conditions at street beverage establishments

No.	Evaluated parameter (Sample size n=45)	Sanitation status	Frequency	Percentage
1	Protective gear	Apron, gloves, and mask present	30	66.67%
		Apron, gloves, and mask absent	15	33.33%
2	Nail hygiene	Trimmed short, clean	34	75.56%
		Long, dirty	11	24.44%
3	Covering utensils	Covered (with glass cabinet)	40	88.89%
		Uncovered	5	11.11%
4	Display and processing equipment	On a table higher than 60 cm	44	97.78%
		On a table lower than 60 cm	1	2.22%
5	Sealing equipment	Using a cup-sealing machine	8	17.78%
		Manual capping by hand	37	82.22%
6	Sanitary waste bins	Closed, sanitary	35	77.78%
		Open	10	22.22%

The results show that most establishments met several criteria related to physical infrastructure relatively well. Specifically, 88.89% of facilities used food-covering utensils, such as glass cabinets or lids, helping to restrict the entry of dust, insects, and environmental contaminants. In addition, 97.78% of facilities arranged display and processing equipment on tables higher than 60 cm, contributing to preventing direct contact between food and dust or ground-level pollution sources. These findings indicate that infrastructure conditions at street beverage points in the study area have generally seen certain improvements compared to the past. Some studies have also pointed out that properly covering food and organizing processing zones can significantly reduce microbial contamination risks in ready-to-eat foods [16], [17].

Regarding factors related to the personal hygiene practices of vendors, the survey results showed that 66.67% of vendors fully utilized protective gear such as aprons, gloves, and masks during beverage processing and serving. Furthermore, 75.56% of vendors had short and clean fingernails, while there were still 24.44% of cases with long or unhygienic nails. Although these indicators are relatively high, the existence of a significant proportion of vendors who do not fully adhere to personal hygiene measures remains a potential factor for microbial contamination. Previous studies have demonstrated that the hands and fingernails of food handlers are common carriers of microorganisms, including *E. coli* and *Staphylococcus aureus*, particularly when hand washing and personal hygiene are not practiced correctly[3], [18].

Additionally, 77.78% of establishments used closed and sanitary waste bins, while 22.22% of facilities left waste exposed. Inadequate waste management can attract insects and vector animals, increasing contamination risks in the food processing environment. Many studies have shown that an unhygienic processing environment, especially improper waste handling, is one of the factors contributing to increased microbial contamination risks in street foods [19].

A notable point in the survey results is that only 17.78% of establishments utilized a machine to seal cups, while 82.22% of facilities still closed lids manually by hand. This practice increases the risk of transmitting microorganisms from the vendor's hands to the beverages, especially when hand hygiene is not guaranteed. According to food safety guidelines from the Food and Agriculture Organization and the World Health Organization, direct hand contact with food or food packaging is one of the most common pathways leading to microbial contamination during preparation and service [1].

In short, the survey results indicate that street beverage establishments in Ea Kao Commune have achieved certain improvements in physical infrastructure and environmental sanitation. However, several factors regarding personal hygiene practices and processing manipulations of vendors remain limited, particularly the use of protective gear and the product capping method. These factors can elevate the risk of microbial contamination in street beverages, thereby affecting consumer health. Therefore, it is necessary to strengthen training activities on food safety knowledge and skills for vendors, while boosting inspection and supervision by regulatory agencies to enhance hygiene conditions during street beverage processing and trading. Hygiene deficiencies at vending establishments could be one of the contributing factors to the heightened microbial contamination risk observed in the street beverage samples analyzed in this study.

3.2. Evaluation of microbial contamination rates in street beverage samples collected in Ea Kao Commune

3.2.1. Evaluation of total platecount (TPC) contamination rate

Total Plate Count (TPC) is one of the key microbiological indicators widely used to evaluate the overall sanitary quality of food and beverages, reflecting potential contamination that may occur throughout processing, storage, and product distribution. According to the regulations on microbial limits in food by the Ministry of Health of Vietnam, ready-to-use beverage products must ensure that microbiological parameters fall within permissible limits to protect consumer safety[5],[11].

The analytical results in this study revealed that 100% of street beverage samples collected in Ea Kao Commune showed the presence of TPC, and all exceeded the permissible limits (Table 5). Specifically, all collected samples of the three surveyed beverage types, namely pennywort juice (RM), passion fruit juice (CD), and peach tea (TD), failed to meet the microbiological standards during both sampling intervals (10:00 AM–12:00 PM and 4:00 PM–6:00 PM). The recorded bacterial density fluctuated from 27.67×10^5 CFU/ml to 192.67×10^5 CFU/ml indicating a very high level of microbial contamination in street beverages within the study area.

Table 5: Inspection of TPC in street beverages collected in Ea Kao Commune

Sample type	**Number of tested samples**	**Morning period (10:00 AM – 12:00 PM)**				**Afternoon period (4:00 PM – 6:00 PM)**			
		Unsatisfactory samples	**Rate (%)**	**Density ($\times 10^5$CFU/ml)**		**Unsatisfactory samples**	**Rate (%)**	**Density ($\times 10^5$ CFU/ml)**	
				Min	**Max**			**Min**	**Max**
RM	15	15	100	57.67	192.00	15	100	73.00	189.00
CD	15	15	100	27.67	192.00	15	100	71.00	191.67
TD	15	15	100	50.6	181.00	15	100	39.67	192.67
Total	45	45	100			45	100		

Note: RM: pennywort juice, CD: passion fruit juice, TD: peach tea.

This outcome can be explained by several factors related to raw material sources, processing procedures, and product storage conditions. Through field observations at business points, juices like pennywort and passion fruit are often prepared early in the morning and stored for long periods before being sold to consumers. Under ambient temperatures fluctuating between 20–30 °C and occasionally exceeding 30°C, microorganisms can grow rapidly if products are not preserved at appropriate temperatures. For peach tea, although there is a heating stage during tea brewing, the addition of ingredients such as syrup, canned peaches, or peach jam after heating, along with opening lids and frequent handling during service, can create conditions for microorganisms from the environment or handlers to enter the product.

Furthermore, sanitation conditions at the business locations can also contribute to increasing microbial contamination levels in street beverages. The survey results in section 3.1 indicate that a significant proportion of vendors did not use full protective gear (33.33%), failed to maintain nail hygiene (24.44%), directly closed product lids by hand (82.22%), and lacked sanitary waste bins (22.22%). These factors can increase the risk of cross-contamination of microorganisms from handlers, utensils, and the surrounding environment into the products.

Pearson correlation analysis between the total plate count (TPC) and various hygiene parameters revealed distinct correlations between sanitary conditions and microbial contamination levels, albeit the correlation strength varied across sample types and sampling periods. Certain variables, such as ambient temperature, display setups, and waste disposal practices, exhibited a negative correlation with bacterial density, suggesting that enhanced sanitation contributed to a reduction in contamination levels. Conversely, positive correlations were observed in specific instances, potentially attributable to uncontrolled confounding factors, including prolonged product storage duration, initial raw material quality, and fluctuating environmental conditions.

The findings of this study are consistent with previous research on street foods and beverages, which noted that microbial density often exceeds acceptable limits due to restrictions in sanitation conditions and food safety controls. Reports from the Food and Agriculture Organization and the World Health Organization also point out that street foods and beverages in many developing nations often carry a high risk of microbial contamination, primarily due to storage at ambient temperatures and uninsured hygiene practices [1]. Overall, the research results show that TABC contamination levels in street beverage samples in Ea Kao Commune are high, reflecting limitations in hygiene conditions and control over processing and storage. This highlights the need to strengthen food safety management measures, and raise the awareness and hygiene practices of vendors to minimize microbial contamination risks and safeguard consumer health.

3.2.2. Evaluation of E. coli contamination rate

Escherichia coli (*E. coli*) is an important indicator bacterium widely used to assess fecal contamination in food and drinking water. The presence of this bacterium in food products indicates potential contamination from water sources, raw materials, or during processing and vendor handling. According to the food microbial limit regulations of the Ministry of Health of Vietnam, *E. coli* must not be detected in 1 mL of ready-to-use beverage samples, as it serves as an indicator organism for the potential presence of enteric pathogens [11].

The analytical results in this study showed that *E. coli* was only detected in pennywort juice (RM) samples, while passion fruit juice (CD) and peach tea (TD) samples were free from this bacteria (Table 6). Specifically, during the morning sampling period from 10:00 AM to 12:00 PM, 6/15 pennywort juice samples were unsatisfactory (40%), with bacterial densities ranging from 30 to 139.67 $\times 10^3$ CFU/ml. In the afternoon period from 4:00 PM to 6:00 PM, the proportion of unsatisfactory samples fell to 3/15 samples (20%), with densities ranging from 17.67 to 125.67 $\times 10^3$ CFU/ml. Taking all 45 surveyed samples into account, the *E. coli* contamination rate was 13.33% in the morning and 6.67% in the afternoon. Although the contamination rate showed a downward trend in the afternoon, the bacterial density in contaminated samples remained high and far exceeded permissible limits.

Table 6: Inspection of *E. coli* in street beverages collected in Ea Kao Commune

Sample type	Number of tested samples	Morning period (10:00 AM – 12:00 PM)				Afternoon period (4:00 PM – 6:00 PM)			
		Unsatisfactory samples	Rate (%)	Density ($\times 10^3$CFU/ml)		Unsatisfactory samples	Rate (%)	Density ($\times 10^3$CFU/ml)	
				Min	Max			Min	Max
RM	15	6	40	30	139.67	3	20	17.67	125.67
CD	15	0	0	0	0	0	0	0	0
TD	15	0	0	0	0	0	0	0	0
Total	45	6	13.33			3	6.67		

Note: RM: pennywort juice, CD: passion fruit juice, TD: peach tea.

The variation in *E. coli* contamination rates among different beverages can be linked to the characteristics of raw materials and processing methods. Pennywort is a raw, fresh ingredient used directly for juicing without undergoing any heat treatment; thus, microorganisms from soil, irrigation water, or leaf surfaces can survive in the raw materials and enter the final product. Conversely, beverages like peach tea involve a heating step during preparation, while passion fruit juice possesses a low pH environment, which can partially inhibit bacterial growth. These factors help explain why *E. coli* was exclusively detected in pennywort juice samples.

In addition, hygiene conditions during preparation and sales play a decisive role in microbial contamination risks. Pearson correlation results indicated that *E. coli* density tended to correlate negatively with hygiene factors such as nail sanitation, covering utensils, and storage temperature, showing that when sanitation conditions are improved, contamination levels decrease. Conversely, the positive correlation between *E. coli* density and the status of waste bins suggests that an unhygienic processing environment can increase cross-contamination from the surroundings.

The results of this study align with numerous previous investigations into street foods and beverages. Several studies have recorded relatively high *E. coli* contamination rates in food or beverage items made from fresh, raw ingredients. A study by Uddin et al. surveyed 20 unpasteurized fruit juice samples of various kinds in Dhaka City, Bangladesh, showing that all samples were contaminated with multiple microorganisms, with half of the total samples containing coliform *E. coli* ranging from 1.00×10^2 CFU/mL to 4.21×10^3 CFU/mL[20]. Another study identified bacterial contamination in samples such as sugarcane juice, orange juice, and mixed fruit juice collected from five busiest markets in Delhi, including Kamla Nagar, Delhi University (North Campus), Tilak Nagar, Chandni Chowk, and Rohini; results revealed that *E. coli* and *Salmonella* were found in high counts in sugarcane juice 2×10^5 CFU/mL and mixed fruit juice 2.2×10^5 CFU/mL [21]. Reports from the Food and Agriculture Organization and the World Health Organization also indicate that street foods and beverages in many developing countries often carry high microbial contamination risks, especially when fresh raw materials are used and hygiene conditions during preparation are not strictly controlled [1].

Overall, the research results show that while most surveyed street beverage samples (passion fruit juice and peach tea) were free from *E. coli*, pennywort juice still presents a substantial contamination risk. The main causes relate to raw ingredient characteristics, a non-heat-treated processing workflow, and insufficient sanitation during sales. Therefore, it is critical to enhance hygiene control over raw materials, processing utensils, and vendor manipulations to limit microbial risks and ensure consumer safety.

3.2.3. Evaluation of Coliforms contamination rate

According to Decision 46/2007/QD-BYT of the Ministry of Health, Coliforms are a bacterial group indicating sanitary quality in food, with a permissible limit in beverages set at 10<CFU/mL. The presence of Coliforms reflects contamination risks from the environment, water, processing utensils, or handler manipulations, while warning of the potential presence of enteric pathogenic microorganisms[1],[11].

The study results showed a distinct difference in Coliforms contamination levels among sample types. Passion fruit juice (CD) samples recorded no Coliforms presence at either survey period, thereby meeting food safety standards. Conversely, pennywort juice (RM) samples showed very high contamination rates, with 13/15 samples (86.67%) being unsatisfactory in both the morning and afternoon. Coliforms density in pennywort juice was also remarkably high, fluctuating from 7.67×10^4 to 197.67×10^4 MPN/mL in the morning and from 25.67×10^4 to 191.67×10^4 MPN/mL in the afternoon. For peach tea (TD) samples, the contamination rate was lower, recorded at 13.33% (2/15 samples) in the morning and 20% (3/15 samples) in the afternoon; however, the Coliforms density still far exceeded the permissible limits, with peak values reaching 80.27×10^4 MPN/mL and 103.33×10^4 MPN/mL, respectively.

Pearson correlation analysis further confirmed the influence of hygiene factors on Coliform contamination levels. In morning pennywort juice samples, Coliforms counts showed a positive correlation with utensil covering conditions and a negative correlation with the use of protective gear, suggesting that inadequate use of personal protective equipment (PPE) may contribute to increased microbial contamination. In peach tea samples, both morning and afternoon periods recorded a negative correlation between Coliforms and hygiene factors like protective gear, processing utensils, and temperature, proving that when sanitation conditions are improved, bacterial contamination drops sharply. However, afternoon pennywort juice samples did not exhibit a statistically significant correlation, possibly due to the concurrent influence of multiple other variables, such as initial raw material sources or storage time.

Regarding the study by Akhtar et al., they surveyed the safety of fresh fruit juices, mixed drinks, and street-vended beverages in Multan, Pakistan, dividing the city into 4 zones for sample collection. Bacteriological analysis of 72 fresh fruit juice, mixed drink, and beverage samples revealed the presence of total viable bacterial count 2. 48 ± 0.16 to 7.91 ± 0.62 log CFU/mL), total coliforms (0.70 ± 0.04 to 4.86 ± 0.29 log CFU/mL), and *E. coli*(0.6 ± 0.03 to 3.83 ± 0.32 log CFU/mL. Qualitative data indicated that apple juice was highly contaminated with fecal coliforms and *Salmonella* spp.[22]. Another study by Mengistu et al. surveyed 78 fruit juice samples including mango, avocado, papaya, and mixed juice collected aseptically from local juice processing facilities and sold at juice houses in Eastern Ethiopia. The results showed that juice samples had total viable bacterial counts at 85.9%, total coliforms at 64.1%, fecal coliforms at 60.3%, and *E. coli* at 33.3%, figures that are higher than maximum permissible limits [23].

From the above results, it can be concluded that passion fruit juice ensures safety regarding Coliforms criteria, while pennywort juice exhibits very high contamination levels and mostly fails to meet standards, and peach tea carries a moderate contamination risk. The primary causes relate to raw material sources, processing hygiene, and storage conditions. Therefore, it is necessary to strengthen control over water sources, input materials, utensil sanitation, protective gear for handlers, and storage conditions to curb Coliforms contamination and ensure food safety for consumers.

Table 7: Inspection of Coliforms in street beverages collected in Ea Kao Commune

Sample type	Number of Tested samples	Morning period (10:00 AM – 12:00 PM)				Afternoon period (4:00 PM – 6:00 PM)			
		Unsatisfactory samples	Rate (%)	Density ($\times 10^4$MPN/ml)		Unsatisfactory samples	Rate (%)	Density ($\times 10^4$MPN/ml)	
				Min	Max			Min	Max
RM	15	13	86.67	7.67	197.67	13	86.67	25.67	191.67
CD	15	0	0	0	0	0	0	0	0
TD	15	2	13.33	30.33	80.27	3	20	45.67	103.33
Total	45	15	33.22			16	35.56		

Note: RM: pennywort juice, CD: passion fruit juice, TD: peach tea.

3.2.4. Evaluation of S. aureus contamination rate

The results in Table 8 demonstrate the presence of *S. aureus* at an alarming level in street beverage samples, especially in the pennywort juice group. Specifically, 60% of pennywort juice samples and 13.33% of peach tea and passion fruit juice samples (collected at both times of the day) were found to contain *S. aureus* with densities exceeding the regulatory limits of the Ministry of Health. The highest densities were recorded in morning pennywort juice (148.00 x10^3 CFU/ml) and afternoon pennywort juice (110.67 x 10^3CFU/mL). For peach tea and passion fruit juice, peak densities reached 179.67 x 10^3 CFU/mL and 82.67 x10^3 CFU/mL in the morning, decreasing to121.67 x10^3 CFU/mL and 73.67 10^3 CFU/mL in the afternoon, respectively.

The high prevalence of *S. aureus* contamination in pennywort juice may be attributed to the nature of its processing workflow, as the product is consumed without heat treatment. During preparation, the raw materials undergo multiple manual handling steps, including washing, cutting, crushing, and filtration, which increase the likelihood of contamination from human-associated microbial sources. *S. aureus* commonly colonizes the skin, hands, and respiratory mucosa of healthy individuals. Therefore, inadequate adherence to personal hygiene practices and the use of insufficiently sanitized processing equipment may facilitate the introduction of this bacterium into the final product. In addition, processing and storing under ambient temperature conditions can also accelerate bacterial growth, intensifying food safety risks [24].

Pearson correlation analysis indicated significant relationships between *S. aureus* density and hygiene factors. In morning pennywort juice samples, there was a positive correlation with covering utensils ($r = 0.482$; $p = 0.001$) and a negative correlation with protective gear ($r = -0.640$; $p = 0.000$), indicating that a lack of protective gear increases contamination risks. In afternoon pennywort juice, *S. aureus* density correlated positively with temperature ($r = 0.448$; $p = 0.002$), reflecting the growth-promoting role of ambient temperature; it also correlated negatively with covering utensils ($r = -0.321$; $p = 0.031$), emphasizing the importance of shielding products. For passion fruit juice, both morning and afternoon periods recorded strong negative correlations between *S. aureus* and factors like protective gear, nail hygiene, waste bins, and temperature (r from 0.596 to 0.923; $p < 0.001$), showing that when hygiene conditions are maintained, bacterial density drops explicitly. Similarly, in morning and afternoon peach tea, *S. aureus* was negatively correlated with protective gear, display-processing utensils, and sampling temperature, confirming the protective role of regulatory hygiene practices.

Another study by Qureshi & Tila examined 315 samples consisting of sugarcane, pomegranate, brown sugar, plum, mango, banana, and apple juices collected aseptically from three Tehsils (including Katlang, Takht Bhai, and Mardan) of Mardan District, Pakistan. Analytical results showed that 96% of the juices possessed high amounts of pathogenic bacteria such as Coliforms (96.82%), *Staphylococcus* (81.90%), and *Salmonella* (64.76%). In Katlang and Takht Bhai Tehsils, all collected samples were contaminated, while in Mardan Tehsil, the bacterial contamination rate was 87.6%. Very high coliform counts were observed in sugarcane juice, apple juice, and raw sugar, with the highest *Salmonella* count being 21.05 10^2CFU/mL in raw sugar and the highest *Staphylococcus* growth in sugarcane juice at 1.22 x 10^3CFU/mL [25].

In general, the results show that *S. aureus* contamination is simultaneously influenced by human factors (personal hygiene, use of protection), environmental conditions (temperature), and processing workflow traits (direct contact, non-heating). Although the sample size was limited, these data provide empirical evidence regarding microbial risks in street beverages, while stressing the need to tighten monitoring, comply with food safety regulations, and raise vendor awareness to protect public health.

Table 8: Results of *S. aureus* inspection in street beverages collected in Ea Kao Commune

Sample type	Number of Tested samples	Morning period (10:00 AM – 12:00 PM)				Afternoon period (4:00 PM – 6:00 PM)			
		Unsatisfactory samples	Rate (%)	Density ($\times 10^3$CFU/ml)		Unsatisfactory samples	Rate (%)	Density ($\times 10^3$CFU/ml)	
				Min	Max			Min	Max
RM	15	9	60	2.00	148.00	9	60	28.67	110.67
CD	15	2	13.33	36.67	82.67	2	13.33	43.67	73.67
TD	15	2	13.33	150.67	179.67	2	13.33	40.33	121.67
Total	45	13	28.87			13	28.87		

Note: RM: pennywort juice, CD: passion fruit juice, TD: peach tea.

In summary, although these analytical results are based on a small sample size, they provide further data on microbial contamination status. This is considered a useful reference source for consumers and relevant functional authorities in food safety and hygiene monitoring and inspection work. Consumers should choose hygienic foods with clear origins, cook foods thoroughly before consumption, and reduce street-side dining habits, especially in high-traffic areas. Vendors must wash hands with soap before processing, use gloves when selling, and comply with food safety and hygiene conditions. Regulatory agencies need to devise better control measures to avoid the trading of low-quality, unhygienic foods that impact consumer health.

IV. Conclusion

Street-vended beverages collected in the study area showed considerable microbial contamination, particularly in non-heat-treated products such as pennywort juice. The presence of foodborne pathogenic bacteria indicates inadequate hygiene practices during processing, storage, and vending. These findings highlight the need for improved sanitation measures, stricter food safety monitoring, and greater awareness among food handlers to reduce potential health risks to consumers.

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