



Research Article

Food Safety Risks in Traditional Palm Wine Production and Consumption: A Cross-Sectional Survey in Côte d'Ivoire

Coulibaly Aminata Nadjoua^{1,*} , Amoikon Tiemele Laurent Simon^{1,2} ,
Pekoula Senaho Fernand¹ , Djeni N'dede Theodore¹

¹Department of Food Science and Technology, Nangui Abrogoua University, Abidjan, Côte d'Ivoire

²Pierre Richet Institute of Bouaké/ National Institute of Public Health, Bouaké Côte d'Ivoire

Abstract

Palm wine is a traditional fermented beverage consumed by over 10 million people in West Africa, yet comprehensive data on hygiene practices and associated health risks remain limited in Côte d'Ivoire. This cross-sectional study assessed sociodemographic characteristics, contamination risk practices, and health outcomes across the palm wine value chain in four Ivorian cities. A total of 560 participants including 80 producers, 80 retailers, and 400 consumers were interviewed using structured questionnaires in Abidjan, Aboisso, Toumodi, and Hiré during the period from September 2019 to April 2020. Data on demographics, production methods, hygiene practices, and self-reported health symptoms were collected and analyzed using chi-square tests and Marascuilo's procedure. Results showed that all producers were male, predominantly Baoulé ethnicity (84.81%), aged 25–34 years (60%), with 43.75% having no formal education. Critical hygiene deficiencies were widespread: 97.82% of producers wore unclean clothing, 21.25% had direct hand contact with the beverage, 98.75% of retailers lacked food safety training, and 72.5% exposed products to open air during sales. Oil palm wine dominated both production (95%) and consumption (80.75%). Among consumers, who were predominantly male (91%) and better educated than producers, 38% reported adverse health effects following consumption. Diarrhea was the most common symptom (69.08% of affected individuals), followed by headaches (15.79%) and abdominal pain (9.87%). Statistical analyses revealed significant associations between production levels and ethnicity, age, education, and palm species ($p < 0.05$). These findings demonstrate that palm wine production in Côte d'Ivoire is characterized by poor hygiene practices that correlate with substantial consumer morbidity. Urgent interventions are needed including mandatory hygiene training, development of good production practices guidelines, and establishment of regulatory frameworks to ensure food safety while preserving this culturally important beverage.

Keywords

Palm Wine, Food Safety, Hygiene Practices, Traditional Fermented Beverages, Côte d'Ivoire, Microbial Contamination

1. Introduction

Palm wine is a traditional alcoholic beverage obtained through the natural fermentation of sap extracted from various

species of palm trees belonging to the Arecaceae family. This milky-white to pale yellow beverage, characterized by its

*Correspondence: Coulibaly Aminata Nadjoua (coulibalynadjoua@gmail.com)

Received: 6 February 2026; Accepted: 20 February 2026; Published: 10 March 2026



Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

sweet-sour taste and varying alcohol content, represents one of the most widely consumed traditional fermented drinks in tropical Africa, with an estimated consumer base exceeding 10 million people across West Africa alone [1]. The beverage holds profound socioeconomic and cultural significance in numerous African societies, where it serves not only as a nutritional source but also plays important roles in social gatherings, traditional ceremonies, and local economies [2].

In Côte d'Ivoire, palm wine production primarily utilizes three palm species: The African oil palm (*Elaeis guineensis*), raffia palm (*Raphia hookeri*), and rônier palm (*Borassus aethiopum*). Among these, oil palm wine constitutes the predominant variety due to the widespread cultivation and natural occurrence of *Elaeis guineensis* throughout the country's forest and pre-forest zones. The extraction process typically involves tapping the sap from felled palm trees, with the extracted liquid undergoing spontaneous fermentation driven by naturally occurring yeasts and bacteria present in the environment, the palm tree itself, and the collection vessels [3]. This spontaneous fermentation process, while producing a beverage rich in vitamins, minerals, and probiotics, also creates significant food safety concerns due to the potential for contamination by pathogenic microorganisms. Additionally, palm wine is highly perishable, with quality and microbial composition changing rapidly within hours of extraction if not stored properly, highlighting the importance of appropriate storage and conservation methods to maintain safety and sensory characteristics.

The microbiological quality of palm wine has been a subject of increasing scientific scrutiny in recent years. Studies conducted across West Africa have documented the presence of diverse microbial populations in palm wine samples, including both beneficial fermenting organisms such as *Saccharomyces cerevisiae* and *Lactobacillus* species, as well as potentially pathogenic bacteria including *Escherichia coli* (*E. coli*), *Staphylococcus aureus* (*S. aureus*), and various coliform bacteria [2, 4]. Research by [1] in Burkina Faso revealed significant variations in microbial loads depending on production methods, storage conditions, and handling practices. Similarly, investigations in Nigeria have reported microbiological contamination levels that frequently exceeded recommended standards for beverages intended for human consumption, raising concerns about potential foodborne disease transmission [5].

The food safety risks associated with palm wine consumption are particularly concerning given the predominantly artisanal and informal nature of its production and distribution systems. Unlike industrial beverage production, which operates under controlled conditions with standardized hygiene protocols, traditional palm wine production remains largely unregulated, with practices varying considerably between producers and regions. The absence of formal training in food hygiene and safety among producers and vendors, combined with inadequate infrastructure and limited access to clean water and sanitation facilities, creates multiple points of potential

contamination throughout the value chain from extraction to consumption [6]. This situation constitutes a major public health problem, as contaminated palm wine can serve as a vehicle for enteric pathogens, contributing to gastrointestinal illnesses and other adverse health outcomes among consumers.

Despite its widespread consumption and recognized importance in local food systems, comprehensive data on the sociodemographic characteristics of palm wine value chain actors and systematic documentation of hygiene practices and associated health outcomes remain scarce in Côte d'Ivoire. Previous studies have primarily focused on microbiological analysis of palm wine samples, with limited investigation into the human factors, practices, and behaviors that contribute to product contamination. Understanding these sociodemographic determinants and risk practices is essential for developing contextually appropriate interventions to improve food safety while preserving this culturally significant traditional beverage.

This knowledge gap is particularly critical given Côte d'Ivoire's position as one of the largest palm oil-producing nations in Africa, with extensive palm cultivation supporting both industrial oil production and traditional wine extraction. The intersection of commercial palm cultivation and artisanal wine production creates unique challenges and opportunities for improving food safety in this sector. Furthermore, as urbanization continues to reshape consumption patterns and market structures, understanding current practices becomes increasingly important for policy development and public health planning.

The present study was therefore designed to address these knowledge gaps through a comprehensive cross-sectional survey examining the palm wine value chain in Côte d'Ivoire. The specific objectives were threefold: first, to characterize the sociodemographic profiles of producers, retailers, and consumers involved in the palm wine sector across four representative cities; second, to identify and quantify hygiene practices and storage practices and behaviors that pose risks for microbial contamination at each stage of the value chain from production through retail to consumption; and third, to document the occurrence and nature of health problems reported by consumers following palm wine consumption. By systematically examining these interrelated dimensions, this research aims to provide evidence-based insights that can inform targeted interventions to enhance food safety in traditional palm wine production while respecting its cultural and economic importance in Ivorian society.

2. Materials and Methods

2.1. Study Design and Site Selection

This study employed a cross-sectional survey design to investigate hygiene practices and health risks associated with palm wine production, distribution, and consumption in Côte d'Ivoire. The research was conducted in four cities selected to

represent different geographical zones and palm wine production systems across the country (Figure 1). Abidjan, located in the southern coastal zone, served as the primary urban center and largest consumer market. Aboisso, situated in the south-eastern region near the border with Ghana, represented an area with traditional raffia and oil palm wine production. Toumodi, located in the central region, was selected for its diversity of palm species including both oil palm and rônier palm. Hir é positioned in the center-west, represented a zone dominated by oil palm cultivation and wine production. These four cities were chosen based on three principal criteria: accessibility for research activities, documented availability of palm wine samples from multiple palm species, and diversity of production techniques reflecting the heterogeneity of palm wine systems in Côte d'Ivoire.

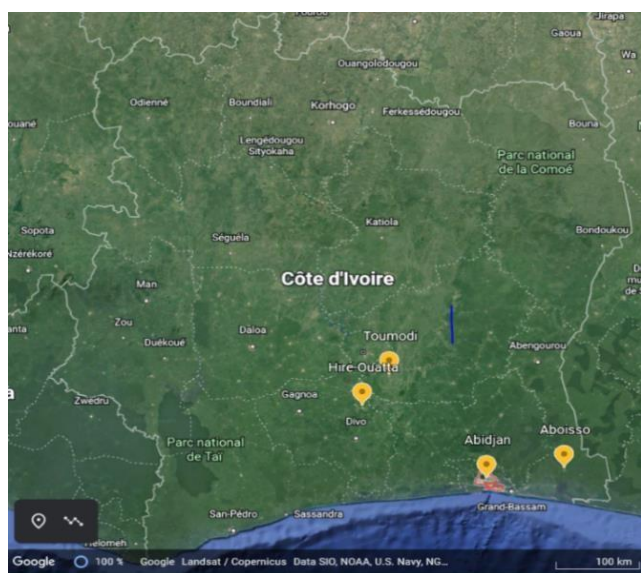


Figure 1. Geographic distribution of study sites in Côte d'Ivoire.

Map showing the four study sites: Abidjan (southern coastal, 5°20'N, 4°02'W), Aboisso (southeastern, 5°28'N, 3°12'W), Toumodi (central, 6°33'N, 5°01'W), and Hir é (center-western, 6°28'N, 5°48'W). Sites were selected to represent diverse palm wine production systems across different agro ecological zones. Total sample: 80 producers, 80 retailers, and 400 consumers.

2.2. Study Population and Sampling

The study population comprised three distinct groups of stakeholders along the palm wine value chain: producers who extract palm sap and oversee initial fermentation, retailers who sell palm wine in markets and informal drinking establishments, and consumers who purchase and consume the beverage. A total of 560 participants were enrolled in the study, including 80 palm wine producers, 80 retailers, and 400 consumers. The sample size for each city was distributed to reflect both population size and production intensity, with 20 producers and 20 retailers recruited from each of the four cities, and

100 consumers recruited from each location. Producers were identified and recruited directly at palm wine extraction sites in outlying and rural areas surrounding each city, where palm trees are tapped and initial collection occurs. Retailers were recruited at established sales points including traditional bars, market stalls, and roadside vendors in urban and peri-urban zones of each city. Consumers were selected through convenience sampling at palm wine consumption sites including bars, social gathering places, and retail points, with efforts made to diversify the sample by approaching potential participants at different times of day and different days of the week. Participation was voluntary and based on informed verbal consent after explanation of the study objectives and procedures. Inclusion criteria for producers required active involvement in palm sap extraction and palm wine production for at least six months prior to the survey. Retailers were required to be actively engaged in palm wine sales as either a primary or secondary economic activity. Consumers were eligible if they reported consuming palm wine at least once per month and were present at the time of survey administration.

2.3. Data Collection Instrument and Variables

Data were collected using structured questionnaires specifically designed for each stakeholder group, with questions adapted to the roles and experiences of producers, retailers, and consumers respectively. The questionnaires were developed in French, the official language of Côte d'Ivoire, with provision for translation into local languages when necessary to ensure participant comprehension. The producers' and sellers' questionnaire focused on topics such as the type of palm wine produced and sold, fermentation duration for producers, the use of adulterating practices like adding water and/or artificial sweeteners, sanitation methods for production/sales sites, and hygiene conditions related to production and marketing. As for consumers' questionnaires, they covered the type of wine consumed, frequency of consumption, and the presence or absence of health issues after consumption. For producers, the questionnaire captured sociodemographic information including age, gender, ethnicity, nationality, level of formal education, and whether palm wine production constituted their principal economic activity. Technical production information included the species of palm tree utilized, the number of daily sap collection rounds, production volumes, and daily income derived from palm wine sales. Questions on hygiene and food safety practices addressed the cleanliness of protective clothing worn during production, use of appropriate protective equipment, cleaning and sanitization of production tools and collection vessels, sanitization of tapping sites, and the occurrence of direct hand contact with the palm sap or fermented beverage. For retailers, sociodemographic data were similarly collected, along with information on the type of palm wine sold, whether retailing represented their primary economic activity, sales volumes, and income. Hygiene practice questions for retailers focused on cleaning methods for sales

vessels and serving containers, storage conditions for palm wine, exposure of the product to open air or environmental contamination, types of containers used for storage and service, attire worn during sales activities, and whether they had received any training in food hygiene and safety principles. For consumers, sociodemographic data included age, gender, and educational level. Consumption pattern questions addressed the type of palm wine preferred, frequency of consumption, typical volume consumed per occasion, and reasons for palm wine consumption. Critically, consumers were asked whether they had experienced any health problems following palm wine consumption, and if affirmative, to describe the specific symptoms experienced including diarrhea, abdominal pain, headaches, vomiting, fever, or other manifestations. Questionnaires were administered through face-to-face interviews conducted by trained enumerators at production sites, retail points, and consumption locations during the period from September 2019 to April 2020. Each interview required approximately 15 to 20 minutes to complete.

2.4. Data Management and Statistical Analysis

Completed questionnaires were checked for completeness and consistency before data entry. All data were coded and entered into a computer database using Microsoft Excel, then imported into statistical software packages for analysis. Statistical analyses were performed using IBM SPSS Statistics version 25.0 and XLSTAT 2022 software. Descriptive statistics were calculated for all variables, with categorical variables presented as frequencies and percentages, while continuous variables were summarized using means and standard deviations where appropriate. Chi-square tests of independence were employed to assess associations between categorical variables, including relationships between sociodemographic characteristics and production levels, sales levels, or consumption patterns. The chi-square test statistic was calculated and compared against theoretical chi-square values at the 0.05 significance level to determine whether observed associations were statistically significant. In cases where chi-square tests revealed significant differences among three or more groups, Marascuilo's post-hoc procedure was applied to conduct pairwise comparisons and identify which specific groups differed significantly from one another. This procedure controls for multiple comparisons and provides critical value ranges for assessing the significance of differences between proportions. For chi-square tests involving two-by-two contingency tables, Yates' continuity correction was applied where appropriate to improve the approximation of the test statistic. Statistical significance for all tests was set at an alpha level of 0.05, meaning that p-values less than 0.05 were considered to indicate statistically significant associations or differences.

2.5. Ethical Considerations

All participants provided informed verbal consent prior to

participating in the study after receiving a clear explanation of the research objectives, procedures, voluntary nature of participation, and confidentiality of responses. Formal ethical approval was not required for this observational survey study as it involved no interventions, collected only anonymous sociodemographic and behavioral data through questionnaires, and posed minimal risk to participants. The study was conducted in accordance with ethical research principles including voluntary participation, informed consent, confidentiality protection, and participant autonomy. Participants were informed of their right to withdraw from the study at any point without consequence and to decline to answer any questions that made them uncomfortable. No personal identifying information such as names or precise addresses was recorded on questionnaires to protect participant confidentiality. All data were stored securely and accessible only to members of the research team.

3. Results

This cross-sectional survey of 560 stakeholders across four Ivorian cities documents sociodemographic characteristics, hygiene practices, and health outcomes throughout the palm wine value chain.

3.1. Sociodemographic Characteristics of Value Chain Actors

Table 1 presents comparative sociodemographic profiles of producers (n=80), retailers (n=80), and consumers (n=400) surveyed across Abidjan, Aboisso, Toumodi, and Hiré

3.1.1. Production Workforce

The production workforce was exclusively male with strong ethnic concentration among Baoulé (84.8%), Attié (5.1%), and other groups (11.3%), reflecting cultural embeddedness of production knowledge. Producers concentrated in prime working years (60.0% aged 25-34, 36.3% ≥35 years), with minimal youth involvement (3.8% aged 18-24).

Educational attainment revealed substantial deficits: 43.8% had no formal education, 22.5% completed only elementary school, and just 6.3% possessed higher education (Figure 2). This inverse relationship between education and production involvement has direct food safety implications, as limited schooling correlates with reduced hygiene awareness. For 80.0% of producers, palm wine represented secondary economic activity, potentially limiting investment capacity. Oil palm wine dominated production (95.0%), with twice-daily tapping by 83.8% of active producers. Direct hand contact with beverages occurred in 21.3% of producers.

3.1.2. Retail Sector

Retailers showed gender reversal from production, with women comprising 63.7% and men 36.3%. Ethnic distribution

remained Baoul é-dominated (78.8%) but with greater diversity. Retailers skewed older (72.5% ≥ 35 years) than producers, suggesting retail as established adult economic activity.

Educational patterns paralleled production: 50.0% lacked formal schooling, and only 1.3% possessed higher education (Figure 2). Critically, 98.8% reported no food hygiene training, meaning virtually all vendors operate without compensatory specialized knowledge. Unlike producers, 71.3% of retailers depended primarily on palm wine sales, suggesting greater responsiveness to quality improvement incentives. Palm wine types handled showed oil palm dominance (80.0%), rônier (13.8%), and raffia (6.3%). Direct hand contact was significantly higher among retailers (47.5%) than producers (21.3%, $p < 0.001$), representing critical pre-consumption contamination risk.

3.1.3. Consumer Profile

Consumers showed male predominance (91.0% vs 9.0% female, $p < 0.001$), reflecting cultural norms. Age distribution balanced across 18-34 years (69.1% combined) with 28.5% ≥ 35 years. Educational attainment substantially exceeded producers and retailers: 25.3% possessed higher education, 23.0% completed high school, and only 16.8% lacked formal schooling (Figure 2). This profile suggests consumers represent more educated population segments who nonetheless engage with informally produced beverages.

Oil palm wine dominated preferences (80.8%), with 12.5% consuming all types. Daily consumption showed 30.3% consuming ≥ 3 liters (heavy), 27.3% consuming 2 liters, 24.8% consuming 1 liter, and 17.8% consuming 0.5 liters (light), indicating substantial exposure potential.

Table 1. Sociodemographic characteristics of palm wine value chain actors.

Characteristics	Producers (n=80)	Retailers (n=80)	Consumers (n=400)	p-value
Gender, n (%)				
Male	80 (100.0)	29 (36.3)	364 (91.0)	<0.001
Female	0 (0.0)	51 (63.7)	36 (9.0)	
Age group (years), n (%)				
12-17	0 (0.0)	3 (3.8)	10 (2.5)	<0.001
18-24	3 (3.8)	5 (6.3)	135 (33.8)	
25-34	48 (60.0)	14 (17.5)	141 (35.3)	
≥35	29 (36.3)	58 (72.5)	114 (28.5)	
Educational attainment, n (%)				
No formal education	35 (43.8)	40 (50.0)	67 (16.8)	<0.001
Elementary school	18 (22.5)	18 (22.5)	55 (13.8)	
Middle school	16 (20.0)	19 (23.8)	85 (21.3)	
High school	6 (7.5)	3 (3.8)	92 (23.0)	
Higher education	5 (6.3)	1 (1.3)	101 (25.3)	
Dominant ethnic group, n (%)				
Baoul é	67 (84.8)	63 (78.8)	—	<0.001
Atti é	4 (5.1)	6 (7.5)	—	
Other	9 (11.3)	11 (13.8)	—	
Primary economic activity, n (%)				
Palm wine related	16 (20.0)	57 (71.3)	—	<0.001

Characteristics	Producers (n=80)	Retailers (n=80)	Consumers (n=400)	p-value
Gender, n (%)				
Other activity	64 (80.0)	23 (28.8)	—	
Palm wine type, n (%)				
Oil palm wine	76 (95.0)	64 (80.0)	323 (80.8)	<0.001
Rônier wine	4 (5.0)	11 (13.8)	10 (2.5)	
Raffia wine	0 (0.0)	5 (6.3)	17 (4.3)	
All types	—	—	50 (12.5)	
Direct hand contact, n (%)				
Yes	17 (21.3)	38 (47.5)	—	<0.001
No	63 (78.8)	42 (52.5)	—	
Daily consumption (liters), n (%)				
0.5	—	—	71 (17.8)	
1	—	—	99 (24.8)	
2	—	—	109 (27.3)	
≥3	—	—	121 (30.3)	
(—) indicate "not applicable" for specific actor categories; p-values from chi-square tests; Statistical comparisons made across actor groups				

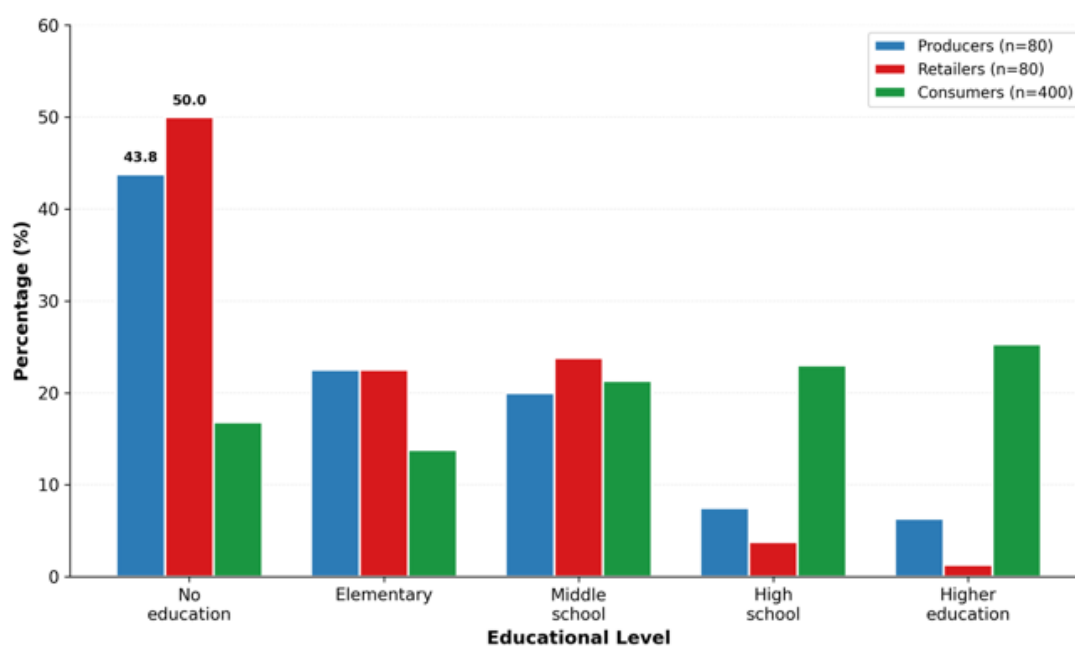


Figure 2. Educational attainment across palm wine value chain actors. Comparison of educational levels among producers (n=80, blue bars), retailers (n=80, red bars), and consumers (n=400, green bars). Producers and retailers show high concentrations of individuals with no formal education.

3.2. Hygiene Practices and Contamination Risks

Table 2 and Figure 3 document systematic hygiene deficiencies across production and retail stages.

3.2.1. Production Stage

Unclean protective clothing affected 97.8% of producers, establishing persistent contamination reservoirs. Additional risks included lacking protective equipment (42.5%), unwashed tools (25.0%), unsanitized production sites (21.3%), and direct hand contact (21.3%). Figure 3 Panel A categorizes these by severity: critical (>90%, red), high (50-90%, orange), and moderate (<50%, yellow) (Table 2).

3.2.2. Retail Stage

Retail deficiencies equaled or exceeded production. No food hygiene training affected 98.8% of retailers, representing critical knowledge gaps. Environmental hygiene was severely deficient: 98.8% cleaned by sweeping rather than washing, 96.3% wore inappropriate attire. Product handling risks included open-air exposure (72.5%), open container storage (48.8%), and direct hand contact (47.5%, significantly higher than producers, $p < 0.001$). Tool hygiene was inadequate: 46.3% used water only without soap, 16.3% never washed tools between customers (62.6% combined inadequate cleaning).

Figure 3 illustrates comparative prevalence, demonstrating retail concentrates more critical-risk practices (three >96% vs one in production).

Table 2. Prevalence of hygiene deficiencies and contamination risk practices.

	Producers (n=80)	Retailers (n=80)	
Risk practice	n (%)	n (%)	p-value
Personal hygiene			
Wearing unclean protective clothing	78 (97.8)	77 (96.3)	0.557
Not wearing appropriate protective equipment	34 (42.5)	—	—
Wearing inappropriate sales attire	—	77 (96.3)	—
Direct hand contact with beverage	17 (21.3)	38 (47.5)	<0.001
Equipment and environmental hygiene			
Tools/vessels not washed before use	20 (25.0)	13 (16.3)	0.164
Tools washed with plain water only	—	37 (46.3)	—
Production/sales site not sanitized	17 (21.3)	—	—
Cleaning by sweeping (not washing)	—	79 (98.8)	—
Product exposure and storage			
Palm wine exposed to open air	—	58 (72.5)	—
Storing in open containers	—	39 (48.8)	—
Training and knowledge			
No training in food hygiene/safety	—	79 (98.8)	—
Overall risk classification			
High risk (≥3 practices)	62 (77.5)	71 (88.8)	0.048
Moderate risk (1-2 practices)	18 (22.5)	9 (11.3)	
Low risk (0 practices)	0 (0.0)	0 (0.0)	
(—) indicate "not applicable" for specific actor categories; p-values from chi-square tests; Statistical comparisons made across actor			

Risk practice	Producers (n=80)	Retailers (n=80)	p-value
	n (%)	n (%)	

groups; Overall risk classification based on number of risk practices present per actor

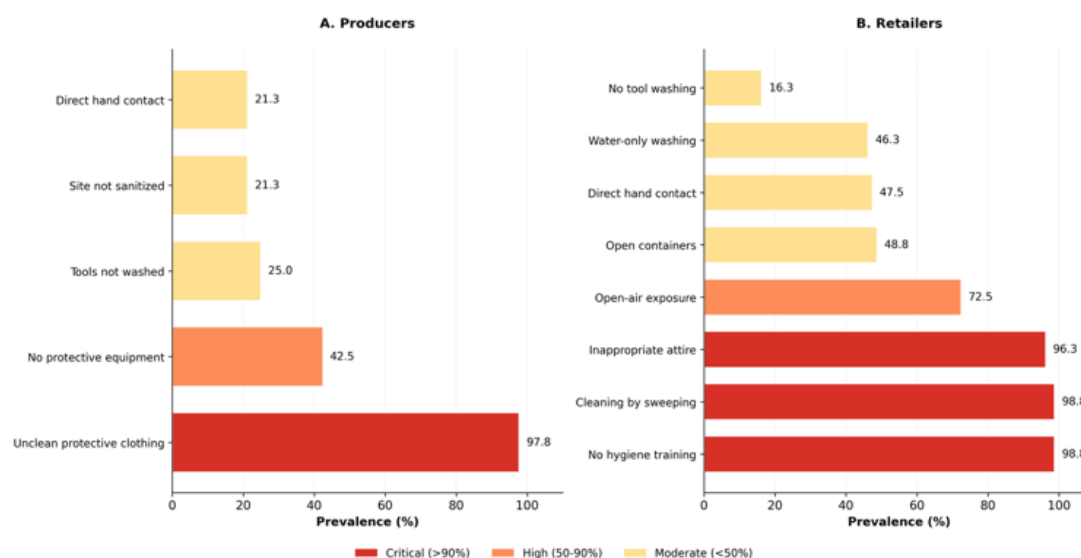


Figure 3. Prevalence of hygiene deficiencies and contamination risk practices.

A: Risk practices among producers (n=80). B: Risk practices among retailers (n=80). Bars color-coded by risk severity: red (critical, >90%), orange (high, 50-90%), yellow (moderate, <50%). Direct hand contact significantly higher among retailers (47.5%) versus producers (21.3%, $p<0.001$). No actors classified as low-risk in either group.

3.3. Risk Classification

Overall risk assessment (Table 2) classified actors by number of risk practices engaged: high risk (≥ 3 practices), moderate (1-2), or low (0). Among producers, 77.5% qualified as high risk, 22.5% moderate. Among retailers, 88.8% qualified as high risk, 11.3% moderate ($p=0.048$). Critically, zero actors qualified as low risk in either group, indicating systematic rather than isolated deficiencies requiring comprehensive interventions.

3.4. Health Outcomes

Table 3 and Figure 4 document adverse health effects among consumers.

3.4.1. Prevalence

Overall, 152 consumers (38.0%) reported adverse effects following consumption versus 248 (62.0%) reporting none ($p<0.001$). Prevalence varied by site: Abidjan and Hiré each showed 50.0% affected, while Aboisso and Toumodi each showed 26.0% ($p<0.001$), likely reflecting production, storage,

or environmental differences.

3.4.2. Symptom Profile

Among symptomatic consumers (n=152), diarrhea overwhelmingly predominated at 69.1% (n=105), strongly implicating enteric pathogens (Figure 4 Panel A, Table 3). Headaches affected 15.8% (n=24), abdominal pain 9.9% (n=15), vomiting 4.6% (n=7), and fever only 0.7% (n=1). Near-absence of fever suggests predominantly non-invasive, toxin-mediated illness rather than systemic invasion. Vomiting showed geographic specificity ($p=0.003$), occurring exclusively in Abidjan (14.0% of affected), potentially indicating site-specific contamination (Figure 4A).

3.4.3. Temporal Onset

Figure 4B and Table 3 show 58.6% (n=89) experienced acute onset within 2 hours, 31.6% (n=48) at 2-6 hours, and 9.9% (n=15) after 6 hours. Acute onset predominance is characteristic of preformed bacterial toxins (particularly staphylococcal enterotoxins), consistent with high retail hand contact (47.5%) and documented *Staphylococcus* presence in palm wine elsewhere.

Table 3. Health outcomes and symptom profiles among palm wine consumers.

Health outcome	Total (n=400)	Abidjan (n=100)	Aboisso (n=100)	Toumodi (n=100)	Hir é (n=100)	p-value
Adverse effects, n (%)						
Any adverse effect	152 (38.0)	50 (50.0)	26 (26.0)	26 (26.0)	50 (50.0)	<0.001
No adverse effects	248 (62.0)	50 (50.0)	74 (74.0)	74 (74.0)	50 (50.0)	
Symptoms (among affected, n=152)						
Diarrhea	105 (69.1)	32 (64.0)	21 (80.8)	21 (80.8)	31 (62.0)	0.231
Headaches	24 (15.8)	8 (16.0)	3 (11.5)	3 (11.5)	10 (20.0)	0.678
Abdominal pain	15 (9.9)	3 (6.0)	2 (7.7)	2 (7.7)	8 (16.0)	0.371
Vomiting	7 (4.6)	7 (14.0)	0 (0.0)	0 (0.0)	0 (0.0)	0.003
Fever	1 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.0)	0.529
Temporal onset (n=152)						
Within 2 hours	89 (58.6)	—	—	—	—	0.079
2-6 hours	48 (31.6)	—	—	—	—	
>6 hours	15 (9.9)	—	—	—	—	
By consumption volume						
0.5 liter/day	21/71 (29.6)	—	—	—	—	0.079
1 liter/day	33/99 (33.3)	—	—	—	—	
2 liters/day	43/109 (39.4)	—	—	—	—	
≥3 liters/day	55/121 (45.5)	—	—	—	—	
(—) indicate "not applicable" for specific actor categories; p-values from chi-square tests; Statistical comparisons made across sites						

(—) indicate "not applicable" for specific actor categories; p-values from chi-square tests; Statistical comparisons made across sites

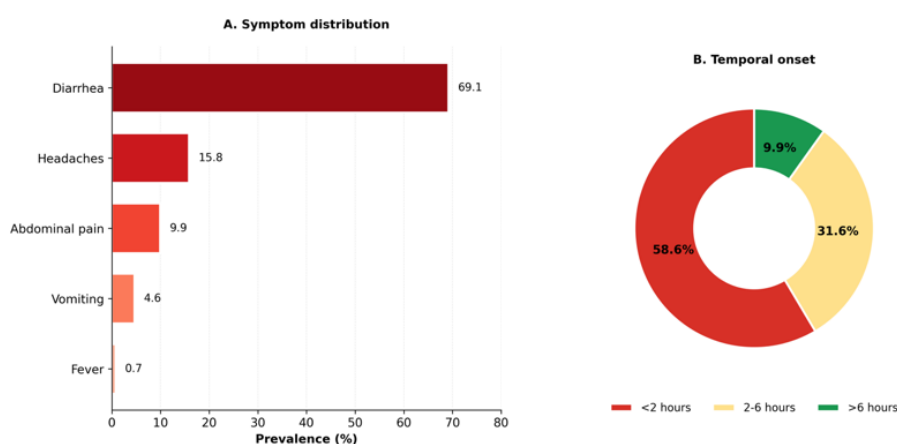


Figure 4. Symptom distribution and temporal onset among affected consumers. A: Prevalence of symptoms among consumers reporting adverse effects (n=152 of 400 total). Diarrhea predominated (69.1%), followed by headaches (15.8%), abdominal pain (9.9%), vomiting (4.6%), and fever (0.7%). B: Time from consumption to symptom onset. Majority (58.6%) experienced acute onset within 2 hours, consistent with preformed bacterial toxins.

3.5. Dose-Response

Table 3 and Figure 6 demonstrate progressive risk increase with consumption volume: 29.6% adverse effects at 0.5 liter/day, 33.3% at 1 liter/day, 39.4% at 2 liters/day, and 45.5% at ≥ 3 liters/day (1.54-fold increase). Linear trend shows strong fit ($R^2 \approx 0.944$) though marginally non-significant ($p=0.079$), likely due to limited sample size in lowest category and overlapping confidence intervals. Pattern suggests cumulative pathogen/toxin exposure increases with consumption volume.

3.6. Synthesis

Figure 5 synthesizes relationships between sociodemographic characteristics, hygiene practices, and health outcomes. Contamination introduced at production through inadequate hygiene (Table 2, Figure 3A) amplifies during uncontrolled fermentation/storage, then intensifies at retail (Table 2, Figure 3B), culminating in substantial consumer morbidity (Table 3, Figure 4). Educational deficits and training absence among producers and retailers (Table 1, Figure 2) contextualize persistent hygiene failures, indicating interventions must address not only behaviors but also structural barriers including limited education, infrastructure deficits, and resource constraints preventing practice improvements even when actors are motivated.

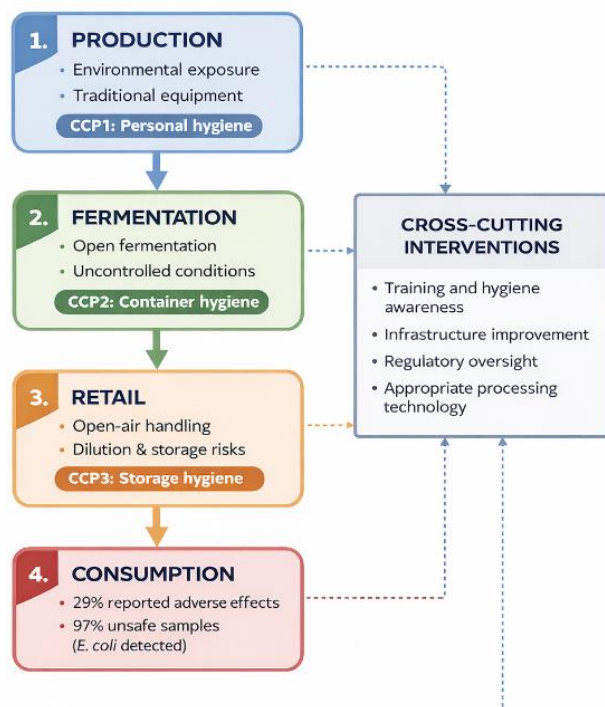


Figure 5. Conceptual framework of contamination pathways and intervention opportunities. Critical control points (CCPs) linked to hygiene deficiencies are identified at each stage. Quantified consumer health outcomes are integrated at the consumption level. Cross-cutting interventions act across the entire value chain to mitigate microbiological risks.

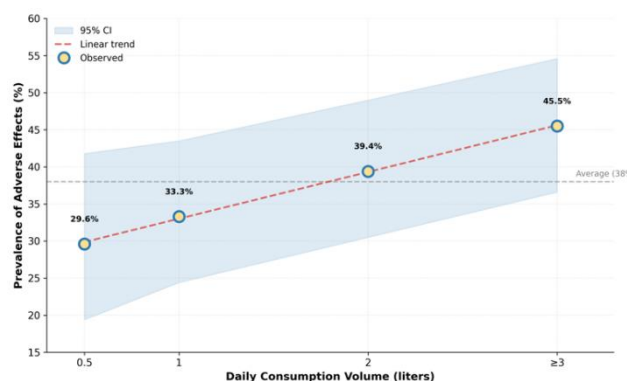


Figure 6. Dose-response relationship between consumption volume and adverse health effects. Prevalence of adverse effects by daily palm wine consumption volume. Data points show observed prevalence at 0.5L (29.6%, $n=21/71$), 1L (33.3%, $n=33/99$), 2L (39.4%, $n=43/109$), and ≥ 3 L (45.5%, $n=55/121$). Shaded area represents 95% confidence intervals. Dashed line shows linear trend ($R^2 \approx 0.944$). Horizontal line indicates overall average (38%).

4. Discussion

This cross-sectional survey of 560 stakeholders reveals systematic hygiene deficiencies and substantial consumer morbidity across Côte d'Ivoire's palm wine value chain, underscoring urgent public health challenges in a traditional beverage sector operating beyond formal regulatory oversight.

The marked ethnic concentration in production, with Baoulé representing 84.8% of producers, reflects deep cultural embeddedness within specific knowledge transmission systems. Indeed, similar patterns have been documented in Nigerian and Cameroonian palm wine systems, indicating that traditional knowledge circulates primarily within closed ethnic networks [2, 7]. While this concentration preserves valuable fermentation expertise accumulated over generations, it simultaneously limits modern food safety principle penetration through conventional public health channels. Consequently, traditional knowledge, though sophisticated in fermentation control, lacks contemporary understanding of microbiology and pathogen control mechanisms [6].

Closely related to this ethnic stratification is the inverse relationship between educational attainment and production/retail involvement. With 43.8% and 50.0% of producers and retailers respectively lacking formal schooling, this educational deficit directly correlates with observed hygiene deficiencies. This association is well-established across multiple contexts, where educational level consistently predicts food safety knowledge and practice adoption [8]. More critically, the finding that 98.8% of retailers have received no food safety training represents a preventable knowledge gap with direct public health consequences. These actors serve as the final checkpoint before consumption, yet they cannot recognize or prevent contamination without appropriate training.

Beyond education and training deficits, demographic patterns reveal additional concerns for sector sustainability. The age concentration among producers, with 60% aged 25-34 years and minimal youth involvement at just 3.8% under age 25, threatens both knowledge transfers and long-term viability. Similarly, research in Benin documented comparable youth disengagement, attributed to urban migration and low-status perceptions of traditional food work [9]. Furthermore, the complete female exclusion from production, contrasting sharply with their retail dominance at 63.7%, reflects broader West African gendered labor divisions. However, women's potential hygiene advantages, documented in Rwandan traditional beer production [10], remain unrealized here, as female retailers showed deficiencies comparable to male producers, confirming that training and resources not gender per se determine outcomes.

Building upon these sociodemographic vulnerabilities, the documented hygiene deficiencies create multiple intersecting contamination pathways that systematically compromise product safety. Palm wine production inherently exposes sap to environmental contamination through open-field extraction processes. As demonstrated by [1], freshly tapped sap already contains diverse microbial populations at 10^3 - 10^5 CFU/mL originating from tree phloem, tapping wounds, and atmospheric deposition. While these microorganisms drive the desired fermentation, they inevitably include potential contaminants that pose health risks.

The producer behaviors documented in our study create specific high-risk scenarios for pathogen introduction and amplification. Most notably, the near-universal practice of wearing unclean protective clothing, affecting 97.8% of producers, establishes persistent contamination reservoirs harboring skin-associated bacteria including *Staphylococcus aureus* and environmental microorganisms that readily transfer to product during handling [11]. Compounding this problem, direct hand contact with beverages reported by 21.3% of producers and significantly higher at 47.5% among retailers is particularly concerning given that production sites typically lack hand-washing facilities. Indeed, studies across West Africa have documented inadequate hand hygiene among informal food handlers, with only 23% of Ghanaian vendors washing hands at critical moments and merely 12% using soap [12].

These behavioral patterns align with microbiological evidence confirming widespread enteric pathogen presence in palm wine across the region. Nigerian studies isolated *E. coli* from 20-60% of samples, while Ghanaian research detected *Salmonella* in 8% [13]. Similarly, Cameroonian investigations identified *Shigella* and other coliforms, with higher contamination levels in longer-stored or ambient-exposed samples [2]. This remarkable consistency across diverse contexts strongly suggests widespread regional contamination patterns, plausibly explaining the high diarrhea prevalence of 69.1% among symptomatic consumers in our study.

Importantly, our finding that 38% of consumers reported

adverse effects with diarrhea predominating and 58.6% showing acute onset within two hours provides compelling evidence linking contamination to health outcomes. The acute onset pattern strongly suggests preformed bacterial toxins, particularly staphylococcal enterotoxins, rather than active infection requiring longer incubation periods [14]. This temporal pattern, combined with the high prevalence of retail hand contact at 47.5% and documented *colipresence* regionally, indicates that contamination with enterotoxin-producing bacteria followed by toxin production during storage may constitute the primary hazard in this value chain.

Nevertheless, the fact that 62% of consumers reported no problems merits careful interpretation. This finding indicates that palm wine consumption is not universally hazardous but likely depends on multiple factors including specific pathogens present, pathogen loads in individual batches, individual host susceptibility, consumption volume, and perhaps protective factors such as acidic pH and alcohol content providing partial antimicrobial effects [1].

When viewed in broader regional perspective, the challenges documented here mirror patterns observed in traditional fermented beverage systems throughout sub-Saharan Africa. For instance, Ethiopian traditional beer production exhibited remarkably similar profiles: 68% of producers lacking formal education, 87% without training, widespread contamination throughout the value chain, and consumer illness rates of 30-40% [15]. Likewise, Ghanaian palm wine systems showed nearly identical deficiencies: 94% of vendors lacking training, 88% using unclean equipment, and 76% with open-air exposure [16]. This cross-national consistency suggests that challenges are fundamentally regional rather than country-specific, implying that validated interventions could be adapted effectively across West Africa.

However, these deficiencies cannot be understood simply as individual behavioral failures but must be recognized as symptoms of deep structural barriers rooted in poverty, informal sector economics, inadequate infrastructure, and systematic policy neglect. The demographic profile revealed in our study characterized by low educational attainment, informal employment status, and socioeconomic disadvantage indicates severe resource constraints that directly limit actors' capacity to implement improved practices. Consequently, recommendations requiring investments that producers cannot afford or infrastructure that does not exist are fundamentally meaningless. For example, advising thorough handwashing is ineffective when production sites lack water supply.

Among these barriers, physical infrastructure deficits constitute perhaps the most fundamental constraint. In rural Côte d'Ivoire, only 68% of the population has access to basic drinking water services, meaning nearly one-third lacks even minimal water availability [17]. Moreover, where water is available, quality is frequently compromised by fecal contamination. Under these conditions, thorough equipment cleaning and hand hygiene become impossible regardless of knowledge or motivation.

Equally problematic is the policy environment, which reflects systematic neglect rather than either effective support or appropriate regulation. Palm wine occupies an ambiguous institutional status culturally important and economically significant to producers yet marginalized as unworthy of policy attention or public investment. This neglect manifests concretely in the absence of quality standards, lacking training programs, non-existent extension services, and minimal research support. Typically, ministries of health focus regulatory attention on formal industries and imports, while ministries of agriculture rarely include traditional fermented foods in their programming priorities [18]. This institutional gap leaves palm wine trapped in regulatory vacuums where neither support nor meaningful oversight exists.

Given these multilevel challenges, addressing the documented problems requires comprehensive interventions that combine immediate risk reduction with longer-term structural transformation. First and foremost, targeted training for producers and retailers could address critical knowledge gaps, but only if designed appropriately for low-literacy populations using visual, demonstration-based approaches delivered in local languages with ongoing support rather than one-time workshops [19]. Encouragingly, Kenyan research demonstrated that participatory hygiene training achieved significant and sustained improvements when delivered in culturally appropriate formats with continued reinforcement [8].

However, training alone cannot overcome infrastructure barriers, making complementary investments essential. Provision of clean water access through protected wells, boreholes, or rainwater harvesting systems would enable the equipment cleaning and hand hygiene that training promotes. Additionally, subsidized food-grade container programs could replace the improvised vessels currently in use. Evidence from Ghana indicates that installation of protected water points near production zones achieved substantial contamination reductions even without extensive behavioral interventions [20].

In parallel, appropriate technology interventions adapted to artisanal production settings could enhance safety without disrupting traditional character. For instance, controlled acidification through food-grade organic acids or acid-producing starter cultures can rapidly lower pH below pathogen-permissive levels while maintaining product acceptability [1]. South African experience with simple starter culture development achieved widespread adoption when products were packaged affordably with pictorial instructions accessible to low-literacy users [19].

Furthermore, regulatory frameworks specifically designed for traditional beverages rather than inappropriate adaptations of industrial standards could provide both structure and positive incentives. Brazil's approach to artisanal sugar cane brandy offers a relevant model: separate regulatory categories with adapted standards, provision of technical assistance, and creation of quality certifications enabling premium market access [21]. Such frameworks balance food safety objectives with economic viability and cultural preservation.

Finally, integration of palm wine safety into broader public health initiatives could leverage existing infrastructure and community trust. Community health worker programs could incorporate palm wine safety messaging into their existing activities around maternal health, nutrition, and water-sanitation-hygiene at modest incremental cost, achieving much wider reach than standalone programs.

5. Conclusions

This cross-sectional survey of 560 stakeholder's highlights systematic food safety challenges across Côte d'Ivoire's palm wine value chain, linking poor hygiene practices to substantial consumer morbidity. Production and distribution suffer from widespread hygiene deficiencies, minimal regulatory oversight, and lack of food safety training, affecting 38% of consumers, primarily with diarrhea. These deficiencies reflect structural barriers such as poverty, limited infrastructure, and policy neglect rather than individual knowledge gaps.

Documented practices including direct hand contact, unclean clothing and equipment, open-air exposure, and inadequate cleaning create multiple contamination pathways. Although 62% of consumers reported no problems, targeted interventions could substantially reduce risk while preserving this culturally and economically important beverage. Recommended measures include low-literacy training programs, improved infrastructure (clean water, proper storage), simple technologies (starter cultures, controlled acidification), adapted regulatory frameworks, and integration into community health initiatives.

The consistency of challenges across West African palm wine systems suggests Côte d'Ivoire validated interventions could be regionally adapted. The goal is not industrialization, but enabling safer production while maintaining traditional character, highlighting the need for political will and resource allocation to protect consumer health in resource-limited contexts.

Abbreviations

CFU	Colony-Forming Units
<i>E. Coli</i>	<i>Escherichia Coli</i>
<i>S. Aureus</i>	<i>Staphylococcus Aureus</i>

Acknowledgments

We are grateful to all the producers, retailers and consumers of palm wine for their free participation in this study.

Author Contributions

Coulibaly Aminata Nadjoua: Formal Analysis, Investigation, Methodology, Writing – original draft

Amoikon Tiemele Laurent Simon: Data curation, Investigation, Methodology

Pekoula Senaho Fernand: Investigation, Writing – original draft

Djeni N'dede Theodore: Conceptualization, Funding acquisition, Supervision, Validation, Writing – review & editing

Funding

This work was also supported by International Foundation For Science (IFS) project E_037779.

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Djeni, T. N., Kouame, K. H., Ake, F. D. M., Amoikon, L. S. T., Dje, M. K., & Jeyaram, K. (2020). Microbial Diversity and Metabolite Profiles of Palm Wine Produced From Three Different Palm Tree Species in Côte d'Ivoire. *Scientific reports*, 10(1), 1715. <https://doi.org/10.1038/s41598-020-58587-2>
- [2] Sumerta, I. N., Ruan, X., & Howell, K. (2024). The forgotten wine: Understanding palm wine fermentation and composition. *International Journal of Food Microbiology*, 408, 111022. <https://doi.org/10.1016/j.ijfoodmicro.2024.111022>
- [3] Oluwole, O., Kosoko, S., Familola, O., Ibrionke, O., Cheikyoussef, A., Raheem, D., Saraiva, A., & Raposo, A. (2023). Fermented traditional wine from palm trees: microbial, nutritional attributes and health impacts. *Frontiers in Food Science and Technology*, 3, Article 1225762. <https://doi.org/10.3389/frfst.2023.1225762>
- [4] Adeiza, Z. D., Joshua, I., Israel, O. A., Danjuma, S. Y., Armstrong, A. A., & Samuel, A. (2023). Microbiological examination of palm wine sold within selected places in Anyigba, Kogi State. *Journal of Food Technology and Preservation*, 5(3), 147.
- [5] Ikeh, I. M., Anele, B. C., Ukanwa, C. C., & Njoku, S. O. (2021). Analysis of the microbial quality of locally consumed palm wine sold in Elele community of Rivers State, Nigeria. *European Journal of Nutrition & Food Safety*, 13(7), 62-69. <https://doi.org/10.9734/ejnf/2021/v13i730437>
- [6] Atalay, Y. A., Gebeyehu, N. A., & Gelaw, K. A. (2025). Food hygiene practice and associated factors among food handlers working in food establishments in sub-Saharan Africa: a systematic review and meta-analysis. *Primary Health Care Research & Development*, 26, e13. <https://doi.org/10.1017/S146342362500009X>
- [7] Mwangi, P. N., Monica, A. W., Maranga, V. N., and Mutisya-Mutungi, M. (2018). Evaluating the food handlers' hygiene practices as determinants of customer choice at selected African indigenous restaurants in Nairobi City County, Kenya. *Journal of Hospitality and Tourism Management*, 5(2), 28-40. <https://doi.org/10.53819/81018102t3064>
- [8] Kindossi, J. M., Anihouvi, V. B., Vieira-Dalodé G., Akissoé N. H., Jacobs, A., Dlamini, N., Pallet, D., and Hounhouigan, J. D. (2012). Production, consumption, and quality attributes of Lanhoun, a fish-based condiment from West Africa. *Food Chain*, 2(1), 117-130. <https://doi.org/10.3362/2046-1887.2012.009>
- [9] Lyumugabe, F., Gros, J., Nzungize, J., Bajyana, E., and Thonart, P. (2012). Characteristics of African traditional beers brewed with sorghum malt: A review. *Biotechnologie, Agronomie, Société et Environnement*, 16(4), 509-530.
- [10] Todd, E. C. D., Greig, J. D., Bartleson, C. A., & Michaels, B. S. (2008). Outbreaks where food workers have been implicated in the spread of foodborne disease, Part 4: Infective doses and pathogen carriage. *Journal of Food Protection*, 71(11), 2339-2373. <https://doi.org/10.4315/0362-028X-71.11.2339>
- [11] Rheinländer, T., Olsen, M., Bakang, J. A., Takyi, H., Konradsen, F., and Samuelsen, H. (2008). Keeping up appearances: perceptions of street food safety in urban Kumasi, Ghana. *Journal of urban health: bulletin of the New York Academy of Medicine*, 85(6), 952-964. <https://doi.org/10.1007/s11524-008-9318-3>
- [12] Addai, T. I., Okolocha, E. C., and Maikai, B. V. (2019). Bacteriological Quality and Occurrence of *Escherichia coli* O157: H7 and *Salmonella* Species in Smoked Rat Meat Sold in Zaria, Nigeria. *Journal of Food and Nutrition Sciences* 7(2) 25-33. <https://doi.org/10.11648/j.jfns.20190702.11>
- [13] Scallan, E., Hoekstra, R. M., Angulo, F. J., Tauxe, R. V., Widdowson, M. A., Roy, S. L., Jones, J. L., and Griffin, P. M. (2011). Foodborne illness acquired in the United States major pathogens. *Emerging Infectious Diseases*, 17(1), 7-15. <https://doi.org/10.3201/eid1701.p11101>
- [14] Fentie, E. G., Emire, S. A., Demsash, H. D., and Dadi, D. W. (2020). Cereal and fruit based Ethiopian traditional fermented alcoholic beverages: A review on their processing, properties, and roles in nutrition and health. *Foods*, 9(12), Article 1781. <https://doi.org/10.3390/foods9121781>
- [15] Mbuagbaw, L., and Noorduin, S. G. (2012). The palm wine trade: occupational and health hazards. *The international journal of occupational and environmental medicine*, 3(4), 157-164.
- [16] World Health Organization & United Nations Children's Fund (UNICEF). (2021). Progress on household drinking water, sanitation and hygiene 2000-2020: Five years into the Sustainable Development Goals (SDGs). WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP). <https://washdata.org/sites/default/files/2021-07/jmp-2021-wash-households.pdf>
- [17] Grace, D. (2015). Food Safety in Low and Middle Income Countries. *International Journal of Environmental Research and Public Health*, 12(9), 10490-10507. <https://doi.org/10.3390/ijerph120910490>
- [18] Holzapfel W. H. (2002). Appropriate starter culture technologies for small-scale fermentation in developing countries. *International journal of food microbiology*, 75(3), 197-212. [https://doi.org/10.1016/s0168-1605\(01\)00707-3](https://doi.org/10.1016/s0168-1605(01)00707-3)

- [19] Cha, S., Kang, D., Tuffuor, B., Lee, G., Cho, J., Chung, J., Kim, M., Lee, H., Lee, J., and Oh, C. (2015). The Effect of Improved Water Supply on Diarrhea Prevalence of Children under Five in the Volta Region of Ghana: A Cluster-Randomized Controlled Trial. *International journal of environmental research and public health*, 12(10), 12127-12143.
<https://doi.org/10.3390/ijerph121012127>
- [20] Anjos, J. P., Cardoso, M. G., Sackz, A. A., D'área, H. S., Santiago, W. D., Machado, A. M. R., Zacaroni, L. M., and Nelson, D. L. (2011). Evolution of the concentration of phenolic compounds in cachaça during aging in an Oak (*Quercus* sp.) Barrel. *Journal of the Brazilian Chemical Society*, 22(7), 1307-1314.
- [21] Neutzling, D. M., Dos Santos, M. S., Dutra de Barcellos, M., and Land, A. L. (2023). Value creation from internationalization of sugar cane by-products: a multi-stakeholder view of artisanal cachaça production. *Revista Brasileira de Gestão de Negócios*, 17(55), 890-910.
<https://doi.org/10.7819/rbgn.v17i55.2134>