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Assessment of Methanol Levels and Labeling Irregularities in Alcoholic Beverages from Yaounde Markets

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Abstract

This study investigates methanol contamination and labeling compliance in alcoholic beverages marketed in Yaoundé, Cameroon. A total of 106 beverages, including spirits, wines, and traditional drinks, were analyzed. Methanol quantification was performed using a modified chromotropic acid spectrophotometric method, while alcohol content was determined by distillation followed by aerometry. Results revealed that 32.1% of beverages exceeded the European Union's methanol safety limit of 50 mg/L, although none reached the acute toxicity threshold of 2000 mg/L (14 mg/kg bw/day). Labeling analysis showed that 13.5% of samples had alcohol content discrepancies, and 16% lacked proper alcohol labeling, particularly among traditional beverages. Additionally, major traceability gaps, such as missing or repeated batch numbers, were observed. While acute methanol poisoning risk appears low, the potential long-term health impacts of chronic low-level exposure remain concerning, especially for heavy consumers. The findings highlight the urgent need for national methanol regulations, stricter labeling enforcement, systematic beverage monitoring, and public awareness initiatives to ensure consumer safety and support public health policy development in Cameroon.

Introduction

The celebration of both joyful and somber events is often accompanied by the consumption of alcoholic beverages such as beer, wine, or spirits. Additionally, some individuals consume alcohol recreationally or as a means of escaping reality, potentially leading to dependence or addiction (Institut National de la Santé et de la Recherche Médicale, 2023). [1] In 2016, alcohol consumption ranked as the seventh leading cause of global mortality, accounting for more than three million deaths (Matene Fongang, 2020) [2]. Cameroon is recognized as the largest consumer of alcohol in Central and West Africa. In 2016 alone, Cameroonians consumed over 660 million liters of beer (Matene Fongang, 2020) [2]. Globally, more than a quarter of alcohol consumption is unrecorded, illicit, or undeclared (Manning & Kowalska, 2021; Probst et al., 2018) [3,4]. In developing countries such as Cameroon, in addition to industrially produced or imported beverages, traditional alcoholic drinks are commonly available; these are often produced with limited mastery of manufacturing practices (Kubo et al., 2014) [5].

Illicit, adulterated, and poor-quality alcoholic products pose serious risks to public health and safety (Manning & Kowalska, 2021) [3]. The lack of strict control over the production process can lead to contamination by harmful substances such as methanol. Methanol (CH_3OH) is a volatile, flammable primary alcohol characterized by a slightly sweet taste and an odor similar to that of ethanol. Methanol in fermented and alcoholic beverages may have a natural origin, resulting from specific fermentation techniques (Aït Daoud et al., 2021; Destanoğlu & Ateş, 2019; Hodson et al., 2017; Ohimain, 2016; Tomsia et al., 2022) [6-9]. However, cases of intentional methanol addition to beverages have been reported, primarily aimed at artificially increasing alcohol content and reducing production costs, often targeting financially vulnerable consumers [7] (Hodson et al., 2017; World Health Organization & Food and Agriculture Organization of the United Nations, 2009) [7,10]. Mass poisonings by methanol-containing liquids have been reported from Russia (Jargin, 2017) [11].

Clinical manifestations of methanol intoxication range from symptoms of drunkenness, gastrointestinal disorders, ocular complications (e.g., optic neuritis), to metabolic and neuropsychiatric disturbances, which may resolve spontaneously within a few hours to days post-ingestion (Sanaei-Zadeh, 2012) [12]. In severe cases, symptoms such as mild mydriasis, bilaterally non-reactive pupils, and profound metabolic acidosis can occur. Methanol ingestion represents a major health hazard due to its potential to cause irreversible organ damage or death if not treated promptly (Ohimain, 2016; Sanaei-Zadeh, 2012; Tomsia et al., 2022). [8,12,9] In light of these health risks, various countries have established regulatory limits for methanol concentrations in alcoholic beverages. Since 2008, the European Union (EU) has set maximum allowable methanol concentrations (per liter of pure ethanol) at 13.5 g/L for fruit brandies, 10 g/L for pomace brandies, and 2 g/L for citrus brandies (Botelho et al., 2020) [13]. In the United States, Australia, and New Zealand, the limit for spirits and fruit brandies is 7 g/L (Botelho et al., 2020) [13]. Regarding wines, the International Organization of Vine and Wine (OIV) recommends maximum methanol concentrations of 250 mg/L for white and rosé wines,

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and 400 mg/L for red wines (Thanasi et al., 2024) [14]. The OIV also mandates specific labeling requirements for wines and spirits, including the product name, actual alcohol content, batch number, and responsible producer's identification (Thanasi et al., 2024) [14].

Physicochemical analyses are essential to ensure both the accuracy of labeled alcohol content and the absence of harmful levels of contaminants such as methanol. Several analytical methods have been developed for methanol detection, including Fourier Transform Infrared Spectroscopy (Sharma et al., 2009) [15], Raman Spectroscopy (Boyaci et al., 2012), [16] enzymatic assays (Kučera & Sedláček, 2017), [17] electrochemical sensors (Kavita et al., 2022), liquid chromatography (Albaseer & Dören, 2022) [18], gas chromatography (Sharma et al., 2009; Zamani et al., 2019) [15,19], and spectrophotometry (Ghadirzadeh et al., 2019; Zamani et al., 2019) [20,19]. Currently, gas chromatography is recognized as the gold-standard method for the determination of volatile alcohols in beverages according to European Commission Regulation (EC) No. 2870/2000, due to its specificity and high sensitivity (Zamani et al., 2019). [19] However, its high operational cost, the requirement for rare gases, and the need for highly specialized personnel limit its routine application in developing countries.

Spectrophotometry using chromotropic acid has been proposed by the OIV as a low-cost alternative for methanol analysis in wines and spirits, although the method remains a Type IV analytical method. A Type IV Method or Tentative Method is a method which has been used traditionally or else has been recently introduced but for which the criteria required for acceptance by the Codex Committee on Methods of Analysis and Sampling have not yet been determined (Codex Alimentarius, 2019). [21] Recent studies have enhanced this method, demonstrating acceptable sensitivity and quantification limits when compared to gas chromatography (Ghadirzadeh et al., 2019; Zamani et al., 2019). [20,19]

The present study aims to assess the exposure risk to methanol among populations in Yaoundé through the consumption of alcoholic beverages. This represents the first investigation of its kind in Cameroon and establishes a foundation for broader research on methanol contamination in the country. The findings also advocate for the implementation of systematic regulatory controls using cost-effective analytical kits.

Methodology

Reagents

The following reagents were used in this study: chromotropic acid, ethanol (100%), methanol (99.9%), and sodium metabisulfite (98%) were purchased from VWR Chemicals (Europe, France). Phosphoric acid (85%), potassium permanganate (>99.5%), and sulfuric acid (98%) were obtained from MERCK (Europe, Germany).

The prepared solutions were:

- Chromotropic acid solution (0.05% in 75% sulfuric acid v/v): Dissolve 50 mg of chromotropic acid (or its sodium salt) in 35 mL of distilled water. Cool the solution in an ice bath, then carefully add 75 mL of concentrated sulfuric acid (density 1.84 g/mL) in small portions while stirring continuously.
- Standard methanol solution: 0.5 g/L methanol prepared in 5% (v/v) ethanol.
- Dilution solution: 50 mL of absolute ethanol diluted to 1 L with distilled water.

Equipment

The actual alcohol content of the beverages was determined using a RAYPA distiller (ENODES, Spain). All weighings were performed with an Adventurer SL analytical balance (OHAUS, Switzerland) with a precision of four decimal places. Alcohol content of the distillates was measured using a series of alcoholometers (ranges 0–10, 20–30, 30–40, and 40–50) supplied by ALLA (ALLA-France, France). Methanol quantification was carried out with a Jenway 7205 UV-Visible spectrophotometer (Cole-Parmer Ltd, UK) following its reaction with chromotropic acid. Samples and analytical equipment were stored at 20°C in a Bio Expert refrigerated incubator (Froilabo, France).

Samples

Samples of wines, spirits, and traditional beverages were collected from July to November 2018 and from June to October 2023 at the Mokolo Market (GPS: 3.8742049 N, 11.502111 E) in Yaoundé, the capital city of Cameroon. Mokolo Market is one of the largest and most populous marketplaces in Central Africa. Beverage brands were selected based on a preliminary survey conducted with market vendors to identify the most frequently consumed products. A total of 106 samples were purchased, representing approximately 80% of the most popular brands across wines, spirits, and traditional beverages. For each brand, three bottles were acquired. The batch number, labeled alcohol content, nominal volume, manufacturer information, and production and expiration dates were recorded for each sample. To maintain confidentiality, brand names are not disclosed in this study.

Specifically, 60 spirit brands, 36 wine brands, and 10 types of traditional beverages were sampled. The products were transported at ambient temperature in containers shielded from direct sunlight and placed in secure areas of the transport vehicle to prevent physical damage. Upon arrival, samples were stored in air-conditioned rooms maintained at 20°C to minimize methanol volatility at elevated temperatures (>60°C).

Determination of the Actual Alcohol Content of Beverages

The actual alcohol content of the beverages was determined using a distillation followed by aerometry method. In this procedure, 200 mL of each beverage sample was distilled using the RAYPA distiller. The distillate was collected in a 500 mL volumetric flask and diluted to the mark with ultra-pure water.

The diluted distillate, along with alcoholometers and a 500 mL graduated cylinder, was placed in an incubator maintained at 20°C

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for one hour to allow thermal equilibration. Following incubation, the equipment and distillate were transferred to an air-conditioned room at 20°C for measurement.

The distillate was carefully poured into the graduated cylinder, and an alcoholometer was immersed into the liquid. Once the alcoholometer stabilized, standing perpendicular to the surface, the reading at the liquid interface was recorded. The recorded value was multiplied by 2.5 to calculate the actual alcohol content of the original beverage. The selection of the alcoholometer was based on the expected alcohol content: the first alcoholometer used corresponded to a range approximately 2.5 times lower than the labeled alcohol percentage. If the alcoholometer was completely submerged, a lower-range instrument was selected; conversely, if it floated excessively with no readable graduation at the surface, a higher-range alcoholometer was employed.

Each measurement was performed in duplicate to ensure reliability. Based on the determined alcohol content, the distillate was further diluted as needed to reach an approximate 5% alcohol concentration for subsequent analytical procedures.

Methanol Quantification in Beverages

The quantification of methanol was based on its oxidation to formaldehyde by potassium permanganate acidified with phosphoric acid, using beverage distillates diluted to 5% (v/v) alcohol. The resulting formaldehyde reacts with chromotropic acid to form a purple-colored complex, which absorbs maximally at 575 nm. The absorbance intensity is proportional to the methanol concentration, as measured by UV-Visible spectrophotometry.

The method applied in this study is a modification of the procedure described by Ghadirzadeh et al., (2019). [20] The principal modification consists of introducing an ice water bath step prior to the addition of saturated potassium permanganate to prevent formaldehyde volatilization and ensure greater reaction stability.

Calibration standards were prepared by diluting 100% methanol into 5% (v/v) ethanol to achieve a stock solution of 500 mg/L methanol. Serial dilutions were then performed by introducing 2.5, 5, 10, 15, 20, and 25 mL of the stock solution into 50 mL volumetric flasks, corresponding to final methanol concentrations of 25, 50, 100, 150, 200, and 250 mg/L, respectively.

For quantification, 500 µL of either a standard solution or a beverage distillate adjusted to 5% (v/v) alcohol was transferred into test tubes. The volume was brought up to the gauge mark with 5% ethanol (prepared by diluting absolute ethanol with ultra-pure water). Subsequently, 50 µL of 50% phosphoric acid was added to each tube. After cooling the tubes in an ice bath, 100 µL of saturated potassium permanganate solution was added. Following a 10-minute reaction time, the excess permanganate was decolorized with 100–200 µL of a 2% neutral sodium sulfite solution.

Then, 5 mL of a 0.05% chromotropic acid solution in 98% sulfuric acid was added to each tube. The tubes were incubated in a water bath at 70°C for 20 minutes, then cooled to room temperature for 20 minutes before absorbance measurements were performed at 575 nm. All measurements were conducted in duplicate to ensure analytical reliability.

Method Validation and Quality Control

All glassware was washed with a mild detergent, rinsed three times with tap water, and subsequently rinsed twice with ultra-pure water prior to use. The linearity of the method was evaluated based on calibration curves constructed from methanol standard solutions at concentrations of 25, 50, 100, 150, 200, and 250 mg/L. Regression lines were generated by plotting concentration against optical density values obtained after chromotropic acid complexation.

Precision was assessed at three concentration levels; each tested in quadruplicate within a single day to evaluate intra-day variability (Equation 1). Intermediate (inter-day) precision was determined by repeating the same spiking tests on two additional, separate days, allowing calculation of inter-day variance (Equation 2). Both intra-day and inter-day precision were expressed as coefficients of variation (CV, %).

To verify the absence of contamination during distillation, blank tests were performed using 5% (v/v) ethanol prepared with ultra-pure water in place of beverage samples. Limits of detection (LOD) and quantification (LOQ) were calculated by analyzing ten blank samples. The LOD was defined as the mean blank value plus three times the standard deviation (SD), and the LOQ as the mean plus ten times the SD.

The maximum method bias was determined as the percentage deviation between the mean spiked sample recovery and the expected theoretical value based on the calibration curve.

Formulas used:

$$V_{intra} = \frac{\sum (n_i - 1) S_j^2}{N - K} \qquad (1)$$

$$V_{inter} = \frac{\sum n_j (m_j - M)^2}{K - 1} \qquad (2)$$

With $S_J^2 = \frac{\sum \left(x_{ij} - m_j\right)^2}{n_j - 1}$

Where:

- S_j^2 = variance of each day,
- n_j = number of replicates per day,
- x_{ij} = i-th value of the j-th day,
- m_j = mean of the j-th day,
- K = number of days,
- N = total number of measurements,
- M = overall mean.

The maximum uncertainty was calculated based on the 95% confidence interval (CI) of the precision tests. Initially, uncertainty of certified reference material (ucrm) was read directly on the label of

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standard solutions. Then, expanded uncertainty of certified reference material (Ucrm) was determined by multiplying ucrm by two (Ucrm = 2 × ucrm). Random uncertainty (U_a) and combined uncertainty (U_c) were then calculated as follows:

$$u_c = \sqrt{U_{crm}^2 + U_a^2} \qquad (3)$$

with $U_a = \frac{S}{\sqrt{n}}$

Finally, the confidence interval was calculated using the student's t-distribution:

CI = +$k_{Student}$ (α, γ) u, c (4)

where:

$k_{Student}$=2.201 (for 11 degrees of freedom, γ=n−1 \gamma = n-1γ=n−1),

α=0.05 (5% risk level).

Evaluation of Human Exposure

Human exposure to methanol through the consumption of alcoholic beverages was estimated using the following equation:

$$E = \frac{C \times q}{p_c}$$

Where :

- E is the exposure value expressed in µg/kg body weight (bw) per day,
- C is the methanol concentration in the beverage (mg/L),
- q is the daily consumption volume (L/day),

P_c is the conventional adult body weight (70 kg), as defined by the WHO and FAO Environmental Health Criteria 240 (World Health Organization & Food and Agriculture Organization of the United Nations, 2009). [10]

The daily consumption value (q) was set at 500 mL (0.5 L) per person, based on data from the National Institute of Statistics (INS) and as reported by Ingenbleek et al., (2017) , [21] representing the intake pattern of heavy consumers.

Data Processing and Statistical Analysis

Data analysis was performed using Microsoft Excel 2016, primarily for plotting calibration curves and calculating descriptive statistics (means, standard deviations, coefficients of variation). Variance analysis (ANOVA) and box plot visualizations were carried out using R software, version 4.0.2, to assess differences between beverage categories and to support statistical interpretations of methanol concentration distributions.

Results and Discussion

Choice of Method

The type IV method described by the International Organization of Vine and Wine OIV (Codex Alimentarius, 2019; OIV, 2009) [21,23] was modified by introducing a cooling step prior to the addition of potassium permanganate to improve method stability and linearity (Figure 1). In the conventional method (Figure 1A), the calibration curve shows moderate linearity (R^2 = 0.9368), likely due to the volatility of methanal formed during the reaction, especially at temperatures above 25°C. This volatility leads to variability in the amount of methanal available for reaction with chromotropic acid, compromising reproducibility.

After modification, the calibration curve (Figure 1B) exhibits significantly improved linearity (R^2 = 0.9988) over the concentration range of 2.5–250 mg/L. The cooling step minimizes methanal loss by volatilization, leading to a more stable and reliable analytical response. Thus, the modified method offers enhanced precision and accuracy for methanol quantification in alcoholic beverages.

Verification of the Performance of the Chosen Method

- **Specificity**

The specificity of the developed method was assessed by testing compounds likely to be present in alcoholic beverages, including glucose, butanol, and propanol, each at 10 mg/L. As presented in Table 1, none of these compounds produced a signal above the limit of quantification (LOQ), indicating that they do not interfere with methanol detection. In contrast, samples containing methanol, whether alone or mixed with propanol or butanol, showed measured concentrations close to the expected values (9.50–10.27 mg/L for 10 mg/L methanol solutions and 4.88 mg/L for 5 mg/L methanol solutions). These results confirm that the method specifically detects methanol without significant cross-reactivity from other alcohols or hydroxylated compounds, thus ensuring the reliability of measurements in complex beverage matrices.

Table 1: Specificity of the method

Sample	Concentration (mg/L)
Glucose (10 mg/L)	< LOQ
Butanol (10 mg/L)	< LOQ
Propanol (10 mg/L)	< LOQ
Methanol (10 mg/L) + Propanol (10 mg/L)	10.27
Methanol (10 mg/L) + Butanol (10 mg/L)	10.08
Methanol (5 mg/L) + Propanol (5 mg/L)	4.88
Methanol (10 mg/L)	9.50
Methanol (10 mg/L)	9.88

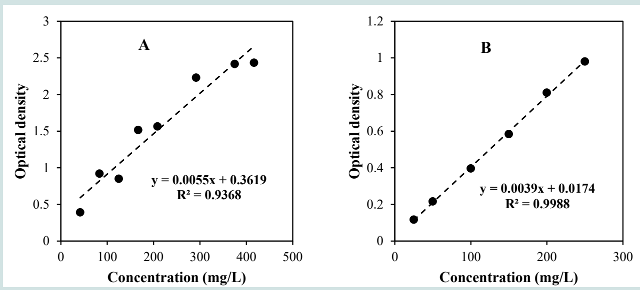

Figure 1: Calibration curves for the quantification of methanol using (A) the conventional OIV method and (B) the modified OIV method.

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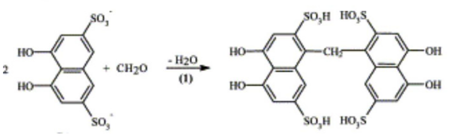
It is evident that chromotropic acid reacts only with methanal according to Equation (6) described by Fagnani, (2003). [24] It does not react with other forms of aldehyde.



(6)

However, if the drink that is to react with chromotropic acid is the result of fermentation that induces the production of formic acid or formaldehyde, the latter will also govern. In this case, we see false positive results (Zamani et *al*., 2019) [19].

- **Limits of Detection and Quantification**

The tests conducted ten times with the blank (0.5% ethanol alcoholic solution) allowed for the calculation of the mean and standard deviation, necessary for determining the limits of quantification (LOQ) and detection (LOD) (Section 2.6). It appears that the limits of quantification and detection are 2.68 mg/L and 0.81 mg/L, respectively. Considering the methanol content in beverages commonly viewed in the literature (>5 mg/L), the quantification and detection limits of the method are therefore appropriate. They are comparable to the detection limits presented by (Ellis et al., 2019) [25] in their work on the quantification of methanol in counterfeit spirits using Raman spectroscopy.

- **Precision, Uncertainties, and Bias**

The precision of the method was evaluated through intra-day and inter-day repeatability tests at concentrations of 25 mg/L and 100 mg/L (Table 2). The intra-day relative standard deviations (RSD) were 1.53% and 2.29% for 25 mg/L and 100 mg/L methanol solutions, respectively, while inter-day RSDs were 2.65% and 9.00%. These values are all below the generally accepted threshold of 10%, confirming good repeatability and intermediate precision of the method. The highest variability was observed in the inter-day test at 100 mg/L, yet it remained within acceptable limits for analytical methods. Overall, the low RSD values demonstrate that the method produces reliable and consistent results under the tested conditions.

(Table 3) also presents the uncertainties and bias of the method. Bias and uncertainty tests demonstrated that the methanol quantification method maintained good analytical performance across all concentration levels. Relative combined uncertainties (Uc%) remained below 6%, and biases ranged from −1.36% to −2.36%, indicating slight but acceptable underestimations. These results confirm the method's accuracy and suitability for reliable methanol analysis in alcoholic beverages.

Table 2: Fidelity test

Compound	RSD (%) intraday			RSD (%) interday		
	25 mg/L	100 mg/L	25 mg/L	25 mg/L	100 mg/L	25 mg/L
Methanol	1.53	2.29	2.65	9.00	6.10	4.39

Table 3: Bias and uncertainties tests

	Methanol		
Parameters	25 mg/L	100 mg/L	250 mg/L
U_a	0.459	1.064	2.978
U_{crm}	0.35	0.4	0.8
U_c	1.305	2.572	6.975
U_c (%)	5.293	2.630	2.858
Bias (%)	-1.36	-2.18	-2.36

Were: U_a: random uncertainty; U_{crm}: expanded uncertainty of the reference material.U_c: Compound uncertainty; U_c (%): relative compound uncertainty

Ethanol and Methanol Content in Beverages: Exposure Evaluation

The analysis of 106 alcoholic beverages, including 60 spirits, 36 wines, and 10 traditional drinks, revealed considerable variability in methanol content depending on the beverage type (Table 4). Among the spirits, 64.1% of samples had methanol concentrations below the limit of quantification (LOQ), whereas 35.9% showed detectable levels, with concentrations reaching up to 138.2 mg/L. Although these levels remained below the acute toxicity threshold of 2000 mg/L (Ohimain, 2016),[8] several whiskey samples exceeded the European Union's recommended safety limit of 50 mg/L, suggesting potential risks related to uncontrolled distillation practices or adulteration (Ellis et al., 2019). [25]

Almost half of the red wine samples (47.4%) exhibited methanol concentrations above 100 mg/L, with the highest recorded value reaching 206.5 mg/L. Nevertheless, all wine samples complied with the OIV regulatory limits for methanol content in red (500 mg/L) and white wines (250 mg/L) (Thanasi et al., 2024). [14] The elevated methanol levels in wines are likely associated with pectin degradation during fruit fermentation, a natural source of methanol production (Md et al., 2013; Navianti et al., 2018). [26,27] [28,29]

Traditional beverages, particularly palm wine and odontol, generally exhibited lower methanol concentrations, ranging from 14.5 to 40.3 mg/L. However, most palm wine samples exceeded limit fixed by National Agency for Food, Drug Administration and Control (NAFDAC) (5 mg/L) for traditional alcoholic beverages (Ohimain, 2016). [8] The absence of specific national standards for methanol content in Cameroon allows such practices to persist, affecting local consumer safety and complicating exports to neighboring countries with stricter regulations.

Labeling and traceability assessments also revealed major deficiencies: 13 beverages (13.5%) showed discrepancies between the actual and declared alcohol content, while 17 samples (16%), mainly traditional beverages, lacked any alcohol labeling. Additionally, 15% of spirits and 39% of wines were missing batch numbers, and some producers assigned identical batch numbers across different brands, suggesting possible fraud or at least poor-quality control practices.

Regarding health risk assessment, the estimated methanol exposure from beverage consumption ranged from 0.02 to 1.48 mg/kg body weight/day. Although these values remained well below the lethal exposure threshold of 14 mg/kg body weight/day (Ohimain, 2016) [8], chronic low-dose exposure could pose long-term health risks, particularly targeting the central nervous system and visual pathways (Sanaei-Zadeh, 2012) [12].

Variance analysis (Figure 2) showed no significant differences between the methanol contents of spirits and wines (P = 0.126) or between spirits and traditional beverages (P = 0.099). However, a

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Table 4: Methanol content of beverages and dietary exposure assessment

Code	Type of drink	Batch number	Alcohol labeling (%)	Actual alcohol content (%)	Methanol content (mg/L)	Methanol exposure (mg/ Kg Pc/J)
			Spirits			
S-1	Gin	OG00119	/	42	<LOQ	N.A
S-2	Gin	999	43	42.5	<LOQ	N.A
S-3	Pastis	1136	43	46.7	<LOQ	N.A
S-4	Pastis	047	43	46.7	<LOQ	N.A
S-5	Coffee rum	2	42.8	40	106.9	0.76
S-6	Rum	29	43	45	<LOQ	N.A
S-7	Rum	1130	43	43	<LOQ	N.A
S-8	Rum	779	43	43	<LOQ	N.A
S-9	Rum	033	43	45	<LOQ	N.A
S-10	Vodka	1	43	43	<LOQ	N.A
S-11	Vodka	1139	43	44.5	<LOQ	N.A
S-12	Vodka	/	43	45	<LOQ	N.A
S-13	Vodka	OR00126	42	39.5	<LOQ	N.A
S-14	Vodka	OR00128	43	43	<LOQ	N.A
S-15	Vodka	OR00132	43	43	<LOQ	N.A
S-16	Vodka	/	43	44.5	<LOQ	N.A
S-17	Whiskey	9873	43	40	50	0.36
S-18	Whiskey	0019	40	37	2.6	0.02
S-19	Whiskey	9875	45	42	138.2	0.99
S-20	Whiskey	9877	42.8	44	<LOQ	N.A
S-21	Whiskey	9878	40	40	113.2	0.81
S-22	Whiskey	9879	42.8	44.8	14.6	0.10
S-23	Whiskey	1133	43	42.4	<LOQ	N.A
S-24	Whiskey	1134	40	40	90.2	0.64
S-25	Whiskey	1135	43	42	<LOQ	N.A
S-26	Whiskey	1137	43	45	<LOQ	N.A
S-27	Whiskey	1138	43	42.9	<LOQ	N.A
S-28	Whiskey	OB00119	/	44	<LOQ	N.A
S-29	Whiskey	OR00119	/	43.2	<LOQ	N.A
S-30	Whiskey	OR00120	/	40	15.1	0.11
S-31	Whiskey	/	/	22	<LOQ	N.A
S-32	Whiskey	/	/	22	<LOQ	N.A
S-33	Whiskey	OJ0013	40	40	70.2	0.50
S-34	Whiskey	OJ136	43	36	25.4	0.18
S-35	Whiskey	OJ335	43	35	22.4	0.16
S-36	Whiskey	9870	43	42	50	0.36
S-37	Whiskey	7659	40	37	21.7	0.16
S-38	Whiskey	0016	43	40	52.2	0.37
S-39	Whiskey	1131	43	42.5	<LOQ	N.A
S-40	Whiskey	/	43	42.9	<LOQ	N.A
S-41	Whiskey	OR00127	43	39	<LOQ	N.A
S-42	Whiskey	OR00129	43	42	<LOQ	N.A
S-43	Whiskey	OR00130	43	42	<LOQ	N.A
S-44	Whiskey	55	43	42.5	<LOQ	N.A
S-45	Whiskey	888	43	41	<LOQ	N.A
S-46	Whiskey	777	43	42	<LOQ	N.A
S-47	Whiskey	007	43	45	<LOQ	N.A
S-48	Whiskey	222	43	42.9	<LOQ	N.A
S-49	Whiskey	/	42	35.2	389.9	2.78
S-50	Whiskey	112	24	24	43.7	0.31
S-51	Whiskey	113	45	35.2	131.4	0.94
S-52	Whiskey	114	43	35	39.9	0.28
S-53	Coffee whiskey	1132	43	41	<LOQ	N.A

S-54	Skimmed whiskey	9876	17	17.5	415.8	2.97
S-55	Skimmed whiskey	/	43	44.5	<LOQ	N.A
S-56	Skimmed whiskey	OR00131	45	40	209.1	1.49
S-57	Skimmed whiskey	/	22	23	<LOQ	N.A
S-58	Skimmed whiskey	/	22	23	<LOQ	N.A
S-59	Fruity Whiskey	Lot N°3	43	40	<LOQ	N.A
S-60	Fruity Whiskey	Lot N°4	43	42.5	<LOQ	N.A
			Wines			
V-1	White wine	L14896502210	8	8	209.9	1.50
V-2	White wine	L14896502210	16	16	71.3	0.51
V-3	White wine	L14896502210	10.5	10	77.0	0.55
V-4	White wine	L18164698134	10.5	10	76.9	0.55
V-5	White wine	/	10.5	10	76.9	0.55
V-6	White wine	L18831	10 à 12	13	59.3	0.42
V-7	Sweet wine	L18164698134	12.2	12.3	<LOQ	N.A
V-8	Sweet wine	L18164698134	12.2	12	186.0	1.33
V-9	Sweet wine	/	/	10	72.4	0.52
V-10	Sweet wine	L18830	10.5	11	59.9	0.43
V-11	Rosé wine	/	10	10	93.7	0.67
V-12	Red wine	/	13	12	164.9	1.18
V-13	Red wine	/	13	12	161.6	1.15
V-14	Red wine	L14896502210	12	10	121.9	0.87
V-15	Red wine	/	14	10.6	110.2	0.79
V-16	Red wine	L18164698134	13	12	<LOQ	N.A
V-17	Red wine	L18164698134	13	12	164.9	1.18
V-18	Red wine	/	13	12	161.6	1.15
V-19	Red wine	/	12	10	121.9	0.87
V-20	Red wine	/	12	10.2	10.2	0.07
V-21	Red wine	L18164698134	9	9	28.9	0.21
V-22	Red wine	L18082837	9	9.6	27.3	0.20
V-23	Red wine	L18086813	9	9.6	20.1	0.14
V-24	Red wine	L18824	9	9.3	15.8	0.11
V-25	Red wine	L18825	11.2	12	20.4	0.15
V-26	Red wine	/	9	12	27.3	0.20
V-27	Red wine	/	12	10.6	19.7	0.14
V-28	Red wine	/	11	10.2	11.1	0.08
V-29	Red wine	L18832	13	12	121.0	0.86
V-30	Red wine	L14896502210	12	10.2	123.3	0.88
V-31	Red wine	/	12.5	10	206.5	1.48
V-32	Red wine	/	13	12	186.0	1.33
V-33	Red wine	L18164698134	13	12	164.9	1.18
V-34	Red wine	L18164698134	13	12	191.2	1.37
V-35	Red wine	L18164698134	11	12	161.6	1.15
V-36	Red wine	L18164698134	13	12	121.9	0.87
			Traditional drinks			
T-1	Palm wine	/	/	5	36.2	0.26
T-2	Palm wine	/	/	6.5	25.2	0.18
T-3	Palm wine	/	/	4.2	40.3	0.29
T-4	Palm wine	/	/	5	28.8	0.21
T-5	Palm wine	/	/	5.4	33.3	0.24
T-6	Odontole	/	/	42	15.1	0.11
T-7	Odontole	/	/	45	17.2	0.12
T-8	Odontole	/	/	47	16.4	0.12
T-9	Odontole	/	/	43	14.5	0.10
T-10	Odontole	/	/	40	29.7	0.21

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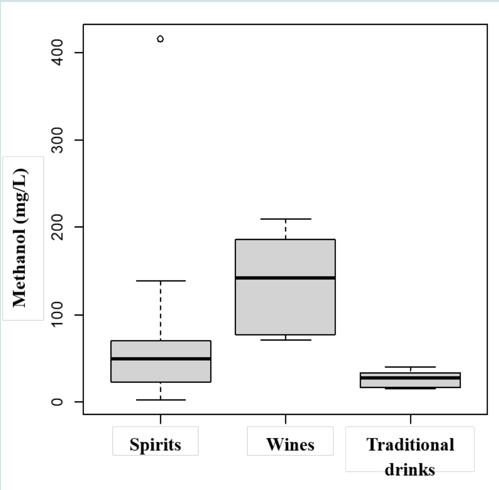

Fgure 2: Whisker plot of methanol concentration as a function of beverage type

significant difference was observed between wines and traditional beverages (P = 0.0003), reflecting greater variability in spirit formulations, particularly among whiskeys of various types (e.g., fruity, skimmed, coffee-flavored varieties).

Overall, these findings underscore the urgent need for Cameroon to establish national regulations governing methanol content in both industrial and traditional alcoholic beverages. In addition, systematic monitoring, stricter labeling enforcement, and public awareness initiatives are essential to protect public health. The significant variability in methanol concentrations, combined with widespread labeling non-compliance, highlights an urgent call for regulatory action. The key implications and recommendations arising from this study are discussed in the following conclusion.

Conclusion

This study provides a comprehensive evaluation of methanol contamination and labeling compliance in alcoholic beverages sold in Yaoundé, Cameroon. Results showed that 32.1% of beverages contained methanol levels exceeding the European Union's safety threshold of 50 mg/L. Although none of the samples reached acute toxicity levels (2000 mg/L or 14 mg/kg/day), the potential chronic effects of low-dose methanol exposure, particularly among heavy consumers, remain a significant concern. Moreover, major labeling deficiencies, including inaccurate alcohol declarations and missing batch numbers, highlight critical gaps in product traceability and regulatory oversight. In the absence of national standards, urgent governmental action is required to establish methanol limits aligned with international guidelines, enforce strict labeling practices, and implement systematic quality controls. Future studies should expand sampling, particularly for locally produced traditional beverages, to better characterize risks and support the development of comprehensive public health policies.

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