International Food Research Journal 24(6): 2435-2441 (December 2017)
Journal homepage: *http://www.ifrj.upm.edu.my*

Quality of spirit drinks in Kibera slums, Nairobi County, Kenya

*Okaru, A.O., Abuga, K.O. and Kibwage, I.O

Department of Pharmaceutical Chemistry, University of Nairobi, P.O Box 19676-00202, KNH, Nairobi

Article history

Received: 15 August 2016
Received in revised form: 11 October 2016
Accepted: 12 October 2016

Keywords

Artisanal spirit
Alcohol strength
Volatiles

Abstract

Cheap licit and artisanal illicit spirit drinks have been associated with numerous outbreaks of alcohol poisoning especially with methanol. This study aimed to evaluate the quality of cheap spirit drinks in Kibera slums in Nairobi County, Kenya. The samples consisted of cheap licit spirits (n=11) and the artisanal spirit drink, 'chang'aa', (n=28). The parameters of alcoholic strength and volatile composition were used as indicators of quality and were determined using GC-FID and GC-MS respectively. The pH of chang'aa was 3.3-4.2 and 4.4-8.8 for licit spirit drinks while ranges for alcoholic strength were 42.8-85.8 % vol. and 28.3-56.7% vol. for chang'aa and licit spirit drinks respectively. The majority of volatiles were found in artisanal spirits and they included higher alcohols, ethyl esters and carbonyl compounds. The alcoholic strength of all the artisanal spirits (100%) and 91% of the licit spirits was above the 40% vol. of standard spirits such as vodka. The high ethanol content of the alcohol products was the only element of public health significance in this study.

Introduction

The World Health Organization (WHO) categorizes alcoholic beverages into recorded and unrecorded alcohol products. Recorded alcohol products are those whose consumption is registered and licit while unrecorded alcohol includes homemade and artisanal drinks such as chang'aa, unregistered or counterfeited drinks and non-beverage or surrogate alcohols derived from medicinal products, automobile products or cosmetics (WHO, 2014; Lachenmeier *et al*., 2009; Rehm *et al.*, 2010). Chang'aa is an artisanal illicit spirit drink obtained from distillation of liquor from fermented maize grains. The alcoholic content of chang'aa is enhanced by addition of sucrose to the fermenting mash before distillation. The production and consumption of the artisanal spirit was first banned in Kenya in 1980 through the Chang'aa Prohibition Act of Kenya but due to the failure of mitigate against the harm arising from the drink, it was legitimized in 2010 by the Alcoholic Drinks Control Bill of 2010 of Kenya. The bill sought to regulate the chang'aa industry with hopes of lowering the prevalence of alcohol poisoning. The Kenya Bureau of Standards (KEBS), a government standards body, also introduced regulation (KS 2326:2011. Traditional Spirit (Chang'aa) – Specification), for the spirit.

According to the WHO estimates, the average adult (15+ years) per capita consumption of unrecorded alcohol is 2.5 L for Kenya (total per capita consumption is 4.3 L) corresponding to 58% (World Health Organisation, 2014). Epidemiological evidence attributes 4% of the global burden of disease to alcohol and there exist a causal relationship of alcohol with more than 60 diseases such as malignant neoplasms, neuropsychiatric disorders, gastrointestinal diseases and diabetes mellitus, liver cirrhosis, injuries and psychosis (WHO, 2002; Rehm *et al*., 2009) and the high content of ethanol has been cited as the main concern for public health in regard to unrecorded alcohol (Lachenmeier *et al.*, 2009; Lachenmeier, Sarsh and Rehm 2009; Rehm *et al*., 2010).

Ethanol and other congeners in spirit drinks can be measured by a variety of methods such as densimetry (Buckee and Mundy, 1993), Fourier transform infrared spectroscopy (Lachenmeier, 2007), refractometry (AOAC,1990), UV/Visible spectrophotometry (AOAC,1990; Caputi *et al*., 1968), enzymatic methods (Rangel, 2000), gas chromatography (AOAC,1990), high performance liquid chromatography (Martin, 1986), Raman spectroscopy (Sanford and Mantooth, 2001), beer analyzer (AOAC,1990) and flow injection analysis (Wagner *et al*., 1992; Martos *et al*., 1998) among others with the choice of method depending on the type of alcohol product being analysed.

Kibera slum is located 5 km southwest of Nairobi Central Business District and is characterised by

*Corresponding author.
Email: *aokaru@uonbi.ac.ke*

poor sewerage and drainage systems and lack of piped drinking water. Slum-dwellers rely on vendors for water supplies and as such the source cannot be ascertained as safe. The ingestion of illicit brews and methanol-laced spirit drinks has been widely reported in Kenya (Ahmad, 2000, Rostrup *et al*., 2016) and socially deprived communities such as slum dwellers are more likely to consume such alcohol products. Indeed, the majority of consumers of alcoholic beverages in this low socio-economic setting are more likely to rely on cheap spirit drinks due to economic constraints and the ready availability (Neufeld *et al*., 2016). Therefore it is important to characterize the volatile components and alcohol strength of the alcoholic beverages in context of consumer safety. This study, therefore, aims to determine the content of ethanol and to qualitatively identify the volatile congeners of cheap spirit drinks in the Kibera slums.

Materials and Methods

Samples

Twenty eight chang'aa samples were obtained from various villages within the Kibera slums. Aliquots measuring 100-200 ml were obtained from each site sampled. The samples were collected in the months of April and May, 2015. For security reasons, a guide was used to locate the chang'aa selling households within the sprawling slums. The chang'aa samples were collected into clean plastic bottles and then coded for blind testing. Licit spirit drinks (n=11) were obtained from Soweto and Laini Saba villages of the Kibera slums.

Chemicals

High purity water was obtained by distillation using an Aquatron Automatic water still A4000 (Bibby Scientific, Staffordshire, UK) while analytical grade ethanol (99.9% v/v) and acetic acid (99.0% v/v) used as a working reference standards were from Scharlau (Sentmenat, Spain). Methanol (99.9% v/v) and n-amyl alcohol (99.9% v/v) were from Sigma-Aldrich (Steinheim, Germany) while acetaldehyde (99.8% v/v), ethyl acetate (98.0% v/v), isobutanol (99.0% v/v) and iso-amyl alcohol (99.0% v/v) were from Merck (NY, USA).

Determination of pH

The pH of the alcohol spirits was determined on 'as-it-is basis' with a Jenway 3510 pH meter (Bibby Scientific, Staffordshire, UK).

Alcoholic strength

The ethanol content was determined using gas chromatography (GC) with flame-ionization detection (FID). A Shimadzu GC-2010 plus (Shimadzu Corporation, Tokyo, Japan) gas chromatograph operated using GC solution software version 2.42 (Shimadzu Corporation, Tokyo, Japan) with a ZB-WAX plus column (60 m × 0.25 mm i.d., film thickness 0.25 µm (Phenomenex, USA) and flame ionization detector was used. Temperature program used was as follows: 40°C hold for 7.5 min, 4°C/min to 200°C, hold for 5 min, 15°C/min to 220°C hold for 5 min. The temperature of the injection port and detector were set at 260°C. The sample preparation is as described in EC regulation 2870/2000 for analysis of volatiles and n-amyl alcohol was used as internal standard. Nitrogen was used as the carrier gas at a flow rate of 2 ml/min. One microliter of each sample was injected into the GC-FID system with a split ratio of 100:1. The method was validated with respect to limit of detection (LOD), limit of quantitation (LOQ), precision and recovery. Quantification was achieved by comparison of peak area ratios of the components to the internal standard against corresponding working reference standards.

Volatile composition

All samples were screened for volatiles including flavour compounds using a Shimadzu QP2010 GC-MS (Shimadzu Corporation, Tokyo, Japan) operated using a GC-MS solution version 2.71 (Shimadzu Corporation, Tokyo, Japan). A split/splitless injector was used while a ZB-WAX plus column (60 m × 0.25 mm i.d., film thickness 0.25 µm (Phenomenex, USA) was used. Temperature was programmed thus: 60°C hold for 1 min, 10°C/min to 190°C, hold for 5 min, 10°C/min to 220 hold for 15 min. The temperature of the injection port and detector were set at 240°C.

The instrument was operated in the electron impact ionization mode at 70 eV taking scans from 0 to 500 m/z in a 1 s cycle. One microliter of each sample was injected in the splitless mode. The mass spectrum obtained were compared against the NIST I and II mass spectral libraries (Standard Reference Data Program, National Institute of Standards and Technology, MD, USA) for identity. A similarity index ≥98% was considered sufficient for identification of analyte compounds.

Results and Discussion

Sample distribution

It was noted that there were few outlets that sold the licit spirit drinks compared to chang'aa. The retail price for about 200 ml of chang'aa ranged between USD 0.50-1.00 while most of the licit spirit drinks

Table 1. Method validation

Parameter	Component							
	Ethanol	Acetaldehyde	Acetic acid	Methanol	Ethyl acetate	1-propanol	Isobutanol	Isopentanol
LOD (mg/100 mL p.a.)	0.02	0.03	0.02	0.02	0.02	0.03	0.02	0.03
LOQ (mg/100 mL p.a.)	0.07	0.08	0.05	0.04	0.07	0.09	0.06	0.08
Precision (% RSD)	1.8	3.2	2.6	1.1	3.4	3.1	3.7	2.1
Recovery (% mean)	100.2	100.5	100.4	102	98	101.3	99.5	98.7

measuring about 250 ml retailed at USD 1.00. A narrow range of similar and cheap brands of the licit spirit drinks were stocked across the retail outlets visited.

Analysis of pH

The pH range of the chang'aa and licit samples ranged between 3.3-4.2 and 4.4-8.8 respectively (Tables 2 and 3). Among the licit drinks, brandies were slightly acidic while whiskey, gin and vodka were slightly basic. The low pH in brandies is associated with the presence of organic acids and sulfur dioxide or the use of sulphuric acid to adjust the pH (Nikicevic and Tesevic, 2005) while slightly basic pH values may be attributed to treatment with alkalinizing agents to enhance the softness of the taste of the drinks (Pereira *et al*., 2013). The chang'aa samples were mildly acidic probably due the high levels of acetic acid of the samples (Table 2).

Method validation

The analytical performance of the GC method used for quantification gave acceptable validation parameters and was considered adequate for the determination of alcoholic strength and volatiles (Table 1).

Alcoholic strength

The alcoholic strength of the chang'aa samples ranged from 42.8% vol. to 85.8% vol. with only eight samples (28.6%) complying with the Kenya standard for chang'aa for alcoholic strength while the rest (71.4%) were above the acceptance criteria (35-57% vol.). Similarly, 91% of the licit spirit drinks had a higher ethanol content than was labelled (range; 28.3% vol. to 56.7% vol.). The alcoholic strength of all the artisanal spirits (100%) and 91% of the licit spirits was above the 40% vol. of standard spirits such as vodka. The drinks offered for sale within this slum are thus able to provide high amounts of ethanol in shorter dinking episodes and in smaller volumes are thus able to produce more pronounced intoxication effects. The high alcoholic strength in spirits poses public health risks to the consumers (Lachenmeier *et al*., 2009; Lachenmeier, Sarsh and Rehm *et al.*, 2009; Rehm *et al.*, 2010). Therefore, there is need for consumer awareness on health hazards attributable to consumption of drinks with high ethanol content.

Volatiles quantified

Acetaldehyde may have arisen from inadequate hygiene and bacterial spoilage of the mashes and production equipment, use of yeast strains with a high production of acetaldehyde and oxidation of ethanol by O_2 during the fermentation under aerobic conditions. Further oxidation of acetaldehyde may result in formation of small amounts of acetic acid (Cole and Noble, 1997). Acetaldehyde was detected in the chang'aa samples only in the range of 0.3-101 mg/100 mL of pure alcohol (p.a.) with a mean content of 17.5 mg/100 mL p.a. However, these levels were within the limits (126.4 mg/100 mL p.a.) set in the Kenyan standard for chang'aa (Table 2).

Determination of the methanol content is important because of the toxicity of its metabolites, formaldehyde and formic acid. Despite the numerous cases of methanol poisoning reported in Kenya, the current study did not detect methanol levels above the Kenyan limit of 5 mg/100 mL p.a. and EU limit for vodka of 10 mg/100 mL p.a., respectively (mean content was found to be 1.4 mg/100 mL p.a.). The low levels of methanol are expected since the production process of the artisanal spirit involves natural fermentation of maize grains and use of high amounts of sugar. Methanol poisoning may be caused by ad-mixture of chemically pure methanol only.

Ethyl acetate results from acetyl-CoA during fermentation because of the continuous oxidation of ethanol to acetic acid and the subsequent esterification (Cole and Noble, 1997). Increased ethyl acetate and 1-propanol concentrations are indicative of prolonged storage of the raw material and probable acetic bacterial spoilage. The highest concentration of ethyl acetate in the chang'aa samples was 3.9 mg/100 mL p.a. with a mean of 0.7 mg/100 mL p.a. No ethyl acetate was detected in the licit brew samples. Nevertheless, all the chang'aa samples complied with the Kenyan limit for ethyl acetate.

Table 2. Analysis results of chang'aa samples

Sample	Alcoholic strength (% vol. at 20 °C)	pH	mg/100 mL pure ethanol (p.a.)							
			Acetaldehyde	Acetic acid	Methanol	Ethyl acetate	1-propanol	*Iso* butanol	*Iso* pentanol	Higher alcohols
K01	66.1±0.22	3.3	58.6	29.6	1.7	0.8	12.9	7.4	93.2	114
K02	85.8±0.32	3.8	44.5	32.2	1.8	0.3	4.3	2.4	25.5	32
K03	76.0±0.17	3.9	32.6	13.3	2.5	0.3	12.8	4.6	124.8	142
K04	58.7±0.25	3.7	100.6	43.6	5.1	2.5	23.2	11.4	160.6	195
K05	63.6±0.36	3.7	101.0	46.2	3.2	3.1	27.8	14.1	191.9	234
K06	60.5±0.59	3.8	46.6	20.5	4.4	3.9	22.6	13.3	229.2	265
K07	72.7±0.33	3.9	36.0	3.6	4.2	1.5	37.7	5.7	279.8	323
K08	48.8±0.38	3.8	34.8	12.2	4.2	2.3	13.3	14.5	306.5	334
K09	68.8±0.10	4.2	24.8	21.0	1.9	1.1	2.0	13.4	71.9	87
K10	49.7±027	3.7	1.1	2.7	ND	0.3	2.2	1.0	17.8	21
K11	62.5±0.20	3.8	0.3	0.1	ND	0.2	2.6	1.1	25.8	29
K12	45.5±0.23	3.7	0.8	1.0	0.1	0.2	2.0	1.0	15.5	18
K13	59.7±0.11	3.9	0.5	1.2	0.3	0.2	1.9	2.7	63.9	69
K14	70.7±0.62	3.8	1.5	1.1	ND	ND	1.6	0.9	8.2	11
K15	58.0±0.69	3.6	3.2	2.7	0.2	0.2	1.3	0.9	15.8	18
K16	53.3±0.48	3.6	3.6	2.4	0.4	0.2	1.7	0.7	13.2	16
K17	76.9±0.92	4.1	2.1	0.3	0.4	0.2	2.0	0.9	14.1	17
K18	59.1±0.63	3.9	1.7	0.9	0.1	0.2	1.2	1.2	26.9	29
K19	42.8±0.56	3.6	2.0	0.7	0.1	ND	1.0	0.7	15.8	18
K20	59.0±0.34	3.9	1.7	2.2	0.5	0.2	2.3	0.9	14.9	18
K21	68.1±0.11	4.2	0.6	0.3	0.8	ND	5.1	0.9	16.9	23
K22	76.2±0.63	4.2	0.6	0.1	0.9	ND	6.5	1.1	23.9	31
K23	63.6±0.51	3.9	0.9	0.7	0.5	0.1	2.2	2.2	59.9	64
K24	49.7±0.55	3.9	0.8	0.2	0.5	ND	3.6	0.5	10.5	15
K25	54.6±0.85	4.1	0.5	0.4	0.3	ND	2.0	0.5	7.6	10
K26	74.4±0.11	3.9	0.7	0.4	0.5	0.9	2.0	0.8	15.3	18
K27	66.6±0.40	3.8	0.4	0.6	0.5	0.2	2.1	0.9	26.1	29
K28	51.6±0.39	3.3	2.4	2.8	0.1	0.3	1.2	0.5	9.2	11
Range	42.8-85.8	3.3-4.2	0.3-101	0.1-46	ND-5.1	ND-3.9	1.0-37.7	0.5-14.5	7.6-307	10-334
Median	61.5	3.8	1.9	1.7	0.5	0.3	2.2	1.0	24.7	29.3
Mean	62.3±10.64	3.8	18.0	8.7	1.4	0.9	7.2	3.8	67.3	78.3
P95	81.8	4.2	85.9	39.6	4. 3	3.1	26.2	13.8	262.1	302.9
Kenyan limit	35-57	-	126.4	-	5	580*	-	-	0.5	0.5

ND- below LOQ, Higher alcohols were calculated by the sum of 1-propanol, *iso*-butanol (2-methyl-1-propanol) and *iso* amyl alcohols, P95 is the 95th percentile of values,- limits not established for the parameter, * total esters expressed as ethyl acetate.

The mean content of 1-propanol in chang'aa was 7.2 mg/100 mL p.a. (range 1.0-37.7 mg/100 mL p.a.). The Kenyan limit for chang'aa set at 0 mg/100 mL p.a. (no precipitate shall formed) is peculiar since artisanally and naturally produced spirits from grains and sugars and even commercially rectified spirits always contain some amount of higher alcohols. Therefore, all the chang'aa samples analysed did not comply with Kenyan limit but are still judged as of no concern to public health (Lachenmeier, Schoeberl, Kanteres *et al*., 2011).

Isobutanol (2-Methyl-1-propanol) concentration in the chang'aa was in the range of 0.5-15 mg/100 mL p.a. with a mean of 3.8 mg/100 mL p.a. while the isoamyl alcohol was in the range of 7.6-307 mg/100 mL p.a. with a mean of 67.3 mg/100 mL p.a. (Table 2). One sample of the licit drinks contained isopentanol (1.7 mg/100 mL p.a.) (Table 3). Isopentanol is formed during fermentation by deamination and decarboxylation reactions from isoleucine (Boulton *et al*., 1996; Kana *et al*., 1988). Elevated concentrations of isoamyl alcohol contribute negatively to the aroma of spirit drinks (Falque *et al.*, 2001). The mean content of higher alcohols, 78.3 mg/100 mL p.a., which is the sum total of 1-propanol, isobutanol and isopentanol, in chang'aa samples was above the limit (0.5 mg/100 mL p.a.) specified by the Kenyan Standard for chang'aa (KEBS, 2011). However, this not of public health significance since these levels are by far lower than the preliminary guideline of 1000 g/hl p.a. for the sum of all higher alcohols that is associated with acute and chronic effects such as liver cirrhosis (Lachenmeier *et al*., 2014). The level (1000 g/hl) is higher than the concentrations usually found in both legal alcoholic beverages and surrogate alcohols (Lachenmeier *et al*., 2008).

Volatiles detected

The volatile congeners qualitatively detected included esters and carbonyl compounds and these are known to confer distinct characteristics to the products. The volatile congeners originate from flavoring agents, raw materials and the subsequent processes such as mashing, fermentation, distillation and aging. The relative concentrations of these compounds vary with some contributing to the flavor and odour of the alcohol products. Nonetheless, the concentrations of these agents may have little

Table 3. Selected analytical results of licit spirits

Sample	Type	Alcoholic strength (% vol. at 20 °C)	pH	mg/100 mL pure ethanol	
				Methanol	Isopentanol
C02	Gin	41.7±0.32	7.6	1.0	ND
C03	Vodka	28.3±0.19	7.8	0.4	ND
C07	Brandy	45.8±0.33	4.8	ND	ND
C08	Brandy	49.1±0.38	4.8	0.1	ND
C13	Vodka	56.7±0.15	7.7	ND	ND
C14	Vodka	49.7±0.49	8.5	ND	ND
C16	Brandy	56.1±0.42	4.4	0.1	1.7
C17	Vodka	50.4±0.90	8.1	0.04	ND
C23	Vodka	57.2±0.52	8.8	0.6	ND
C24	Gin	51.3±0.47	8.4	0.4	ND
C25	Vodka	48.7±0.34	7.7	ND	ND

ND- Below LOQ, Higher alcohols were calculated by the sum of 1-propanol, *iso*-butanol (2-methyl-1-propanol) and *iso*-amyl alcohols.

Table 4. Volatile constituents identified in *chang*'aa samples

	Sample composition										
Sample	ACA	ACO	ACT	2,3-Bu	ACON	ECPL	ECPN	FA	Suc	EL	EPT
RT (min)	5.3	5.8	6.2	7.0	11.7	13.7	16.85	17.2	17.4	20.3	28.8
K01	-	-	-	-	-	-	-	-	-	-	-
K02	+	-	-	-	-	-	-	-	-	-	-
K03	-	-	-	-	-	-	-	-	-	-	-
K04	-	-	-	-	-	+	+	-	+	-	-
K05	-	-	-	-	-	-	+	-	-	-	-
K06	-	-	-	-	-	-	+	-	-	-	-
K07	+	-	-	-	+	-	+	+	-	+	+
K08	+	-	-	-	-	-	-	-	+	-	-
K09	-	-	-	-	-	-	-	+	-	-	-
K10	-	-	-	-	-	-	+	+	-	-	-
K11	+	-	-	-	-	-	+	-	-	+	-
K12	+	-	-	-	+	-	-	-	-	-	-
K13	+	-	-	-	-	-	-	-	-	-	-
K14	-	-	-	-	-	-	+	+	+	+	-
K15	-	-	-	-	-	-	+	-	+	-	-
K16	-	-	-	-	-	-	+	-	+	-	-
K17	+	-	-	-	-	-	+	-	-	+	-
K18	+	-	-	-	-	-	+	-	+	+	-
K19	+	-	-	-	-	-	-	+	-	-	-
K20	-	-	-	-	-	-	+	+	-	+	-
K21	+	+	+	+	-	-	+	+	-	+	+
K22	+	+	+	+	+	+	+	-	-	+	+
K23	+	+	+	+	+	-	+	+	-	-	-
K24	+	+	+	+	+	-	+	+	-	-	-
K25	+	+	+	+	+	-	+	+	-	+	-
K26	+	-	-	+	-	-	+	-	-	-	-
K27	+	-	-	+	-	-	+	-	-	-	-
K28	+	-	-	+	-	+	-	+	-	-	-

ACA-Acetaldehyde, ACO-Acetone , ACT-Acetal, 2,3-but - 2,3-butadione, ACON - Acetoin , FA – 2-Furfural, ECPL- Ethyl caprylate, ECPO- Ethyl caproate, ECPN- Ethyl caprinate , EL- Ethyl laurate, EPT – Ethyl palmitate, EPD – Ethyl pentadecanoate, Hep – Heptanoic acid,, Succ- Succinic acid and PhEt – Phenethyl alcohol, + - Detected, - - Not detected, Hep. was only detected in K28 while EPD was in K03 and K04, ECPO in K21

relationship to the perceived olfactory characteristics of a product (MacNamara and Hoffmann, 1998). The majority of the volatiles were observed in artisanal spirits compared to licit spirits and there were differences in 'typicities' of the volatile profiles of artisanal spirits since the starting materials and art of brewing differ among producers from different communities in the slums. Ethyl acetate, 1-propanol, isobutanol, isopentanol, ethyl lactate, 2, 3-butanediol and acetic acid were present in all samples of the artisanal spirits.

Carbonyl compounds result from spontaneous or microbially-mediated oxidation. The carbonyls detected in the samples include acetaldehyde, acetone, acetoin, furyl alcohol, 5-hydroxymethyl furfural and furfural (Table 4). Furfural (2-furfural) and 5-hydroxymethyl furfural (HMF) are furanic derivatives formed during distillation due to dehydration of residual fermentable pentose sugars, xylose and rhamnose, respectively. The dehydration is caused by unfavourable fermentation conditions such as heating in acid conditions and/or Maillard reaction (Mangas et al., 1996; Cole and Noble, 1997). In our study, furfural was detected in ten chang'aa samples while 5-HMF occurred in only one of the licit spirit drinks, C13. This could be attributed to the uncontrolled distillation conditions employed in the production of chang'aa. Phenylethanol, a tail fraction, was detected in 26 of the 28 chang'aa samples while it was not detected in the licit spirit drinks (Table 4).

This could be attributed to the inefficient distillation conditions employed in the production of chang'aa. Other components detected in licit spirit, C24, were benzyl alcohol and α-terpineol, a terpenoid used as a flavoring agent.

Esters are responsible for the sensory characteristics of spirits, giving them a pleasant fruity smell and they arise during fermentation processes of organic acids and alcohols. Ethyl esters of fatty acids are the most important aroma compounds in the spirit drinks. They are enzymatically produced during yeast fermentation and from ethanolysis of acyl-CoA that is formed during fatty acids synthesis or degradation (Apostolopoulou *et al*., 2005). Six ethyl esters were identified in illicit spirits and one in licit spirit drink, C16 , namely ethyl caprylate, ethyl acetate, ethyl butyrate and ethyl caproate. Ethyl lactate serves to stabilize the distillate flavour and softens the harsh flavour characteristics present in low concentrations. The presence of lactic acid bacteria increases its concentration and contributes negatively to the distillate organoleptic quality (Apostolopoulou *et al*., 2005). Ethyl lactate was detected in all chang'aa samples and but not in licit spirit drinks.

Conclusion

This study in Kenya, which found extreme and unlabelled alcoholic strengths in unrecorded spirits, corroborates results from other countries (see Lachenmeier, Leitz, Shoeberl *et al*., 2011; Rehm *et al*., 2014) namely that the only common element is the higher alcoholic strengths of unrecorded products compared with licit spirits. The public health relevance of this observation is especially grave because the higher content of ethanol is not labelled on the products and thus the consumer may ingest more alcohol than with recorded spirits.

Acknowledgments

The authors are grateful to the German Academic Exchange Service (DAAD) for the scholarship awarded to Alex Okaru and the Deans Committee, University of Nairobi, for funding this research.

References

Ahmad, K. 2000. Methanol-laced moonshine kills 140 in Kenya. The Lancet 356(9245): 1911.

AOAC. 1990. Official Methods of Analysis. 15th ed. Washington DC: Association of Official Analytical Chemists, Inc.

Apostolopoulou, A.A., Flouros, A.I., Demertzis, P.G. and Akrida-Demertzi, K. 2005. Differences in concentration of principal volatile constituents in traditional Greek distillates. Food Control 16: 157-164.

Boulton, R.B., Singleton, V.L., Bisson, L.F. and Kunkee, R.E. 1996. Principles and practices of wine making. New York: Chapman and Hall.

Caputi, A.Jr., Ueda, M. and Brown, T. 1968. Spectrophotometric determination of ethanol in wines. American Journal of Enology and Viticulture 19: 160-165

Cole, V.C. and Noble, A.C. 1997. Flavour chemistry and assessment. In Lea, A.G.H. and Lea, P.J.R. (Eds). Fermented Beverage Production, p. 361-385. London: Blackie Academic and Professional.

Buckee, G.K. and Mundy, A.P. 1993. Determination of Ethanol in Beer By Gas Chromatography (Direct Injection)-Collaborative Trial. Journal of the Institute of Brewing 99(5): 381–384.

Falque, E., Fernandez, E. and Dubourdieu, D. 2001. Differentiation of white wines by their aromatic index. Talanta 54: 271–281.

Kenya Bureau of Standards (KEBS) 2011. KS 2326:2011. Traditional Spirit (Chang'aa)-Specification. Nairobi: KEBS

Lachenmeier, D.W. 2007. Rapid quality control of spirit drinks and beer using multivariate data analysis of Fourier transform infrared spectra. Food Chemistry 101(2): 825–832.

Lachenmeier, D.W., Haupt, S. and Schulz, K. 2008. Defining maximum levels of higher alcohols in alcoholic beverages and surrogate alcohol products. Regulatory Toxicology and Pharmacology 50(3): 313-321.

Lachenmeier, D.W., Ganss, S., Rychlak, B., Rehm, J., Sulkowska, U., Skiba, M. and Zatonski, W. 2009. Association Between Quality of Cheap and Unrecorded Alcohol Products and Public Health Consequences in Poland. Alcoholism Clinical and Experimental Research 33(10): 1757-1769

Lachenmeier, D.W., Sarsh, B. and Rehm, J. 2009. The composition of alcohol products from markets in Lithuania and Hungary, and potential health consequences: A pilot study. Alcohol and Alcoholism 44(1): 93-102.

Lachenmeier, D.W., Schoeberl, K., Kanteres, F., Kuballa, T., Sohnius, E.M. and Rehm, J. 2011. Is contaminated unrecorded alcohol a health problem in the European Union? A review of existing and methodological outline for future studies. Addiction 106(s1): 20-30

Lachenmeier, D.W., Leitz, J., Schoeberl, K., Kuballa, T., Straub, I. and Rehm, J. 2011. Quality of illegally and informally produced alcohol in Europe : Results from the AMPHORA project. Adicciones 23(2): 133-140.

Lachenmeier, D.W., Monakhova, Y.B. and Rehm, J. 2014. Influence of unrecorded alcohol consumption on liver cirrhosis mortality. World Journal of Gastroenterology 20(23): 7217-7222.

MacNamara, K. and Hoffmann, A. 1998. Gas chromatographic technology in analysis of distilled spirits. In David, L.B.W. and George C. (Eds). Instrumental Methods in Food an Beverage Analysis, p. 303-346. Amsterdam: Elsevier Science BV

Mangas, J., Rodrıguez, R., Moreno, J. and Blanco, D. 1996. Changes in the major volatile compounds of cider distillates during maturation. Lebensmittel-Wissenschaft und Technologie 29: 357-364.

Martin, E., Iadaresta, V., Giacometti, J.C. and Vogel, J. 1986. Ethanol determination by HPLC in alcoholic beverages. Mitteleungenausdem Gebiete der Lebensmitteluntersuchungun Hygiene 77: 528-534

Martos, I.L., Sartini, R.P., Zagatto, E.A.G., Reis, B.F. and Giine, M.F. 1998. Spectrophotometric flow injection determination of ethanol in distilled spirits and wines involving permeation through a silicon tubular membrane. Annals of Science 14: 1005-1008

Neufeld, M., Lachenmeier, D.W., Hausler, T. and Rehm, J. 2016. Surrogate alcohol containing methanol, social deprivation and public health in Novosibirsk, Russia. International Journal of Drug Policy doi: 10.1016/j.drugpo.2016.08.001

Nikicevic, N. and Tesevic, V. 2005. Possibilities for methanol content reduction in plum brandy. Journal of Agricultural Sciences 50(1):49-60

Pereira, E.V.S., Oliveira S.P.A., Nobrega, I.C.C., Lachenmeier, D.W., Adelia, A.C.P., Telles, D.L. and Silva, M. 2013. Brazilian vodkas have undetectable levels of ethyl carbamate. Quimica Nova 36(6): 822-825

Rangel, A.O.S.S. and Toth, I.V. 2000. Enzymatic determination of ethanol and glycerol by flow injection parallel multi-site detection. Analytica Chimica 416(2): 205-210

Rehm, J., Mathers, C., Popova, S., Thavorncharoensap, M., Teerawattananon, Y. and Patra, J. 2009. Global burden of disease and injury and economic cost attributable to alcohol use and alcohol-use disorders. Lancet 373(9682): 2223–2233.

Rehm, J., Kanteres, F. and Lachenmeier, D.W. 2010. Unrecorded consumption, quality of alcohol and health consequences. Drug and Alcohol Review 29(4): 426–436.

Rehm, J., Kailasapillai, S., Larsen, E., Rehm, M.X., Samokhvalov, A.V., Shield, K.D. and Lachenmeier, D.W. 2014. A systematic review of the epidemiology of unrecorded alcohol consumption and the chemical composition of unrecorded alcohol. Addiction 109(6): 880–893.

Rostrup, M., Edwards, J.K., Abukalish, M., Ezzabi, M., Some, D., Ritter, H., Menge, T., Abdelrahman, A., Rootwelt, R., Janssens, B., Lind, K., Paasma, R. and Hovda, K.E. 2016. The Methanol Poisoning Outbreaks in Libya 2013 and Kenya 2014. PLoSONE 11(3): e0152676.

Sanfoed, C.L. and Mantooth, B.A. 2001. Determination of ethanol in alcohol samples using a modular Raman spectrometer. Journal of Chemistry Education 78: 1221

Wagner, K., Bilitewski, U. and Schmid, R.D. 1992. Flow injection analysis of wine-accomplishments and needs. Microchemistry Journal 45: 114-120

World Health Organisation 2002. World Health Report 2002 - Reducing risks, Promoting healthy life. Geneva: World Health Organization.

World Health Organisation 2014. Global status report on alcohol and health. Geneva: World Health Organization