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# Traditional Processing and Quality Control of the “Red Kapsiki”: A Local Sorghum Beer from Northern Cameroon

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## Abstract

This study was propose to elucidate the traditional process production, biochemical, and microbiological parameters of the “red kapsiki” beer locally called “Te.” Direct interviews are conducted on the basis of questionnaires in four localities of the Far-North region of Cameroon. At each site, beer samples are collected, labeled, and undergo physicochemical and microbiological analyses using standardized methods. The results show that the traditional “red kapsiki” beer process incorporates a malting step, a large brewing stage, and a final fermentation step which requires a starter. The biochemical parameters of the beer samples show a pH value ranging from  $2.40 \pm 0.19$  to  $3.26 \pm 0.03$  ( $\text{pH} < 4.5$ ), an alcohol content between  $3.85 \pm 0.58$  and  $4.28 \pm 0.78\%$  (v/v), a soluble extract which varies from  $6.30 \pm 1.09$  to  $7.29 \pm 0.26$  °P, a total sugar content which fluctuates between  $41.8 \pm 0.39$  and  $72.9 \pm 0.40$  g/L. In addition, the “red kapsiki” beer shows a total polyphenol content between  $843 \pm 27$  and  $1150 \pm 27$  mg/L and a flavonol level fluctuating between  $750 \pm 23$  and  $1300 \pm 27$  mg/L. Microbial analyses show a poor hygienic quality according to Cameroon standards referenced on the French Agency Norms.

**Keywords:** Cameroon, beer, homemade, processing, biochemistry, microbial, quality

## 1. Introduction

The artisanal fermentation of cereals into beers and wine-like alcoholic drink is not recent in Africa. The traces of the first artisanal fermentation were found by archaeologists in the

Blue Nile region of Sudan [1, 2]. In mountainous area of central African savannah, cereals, mainly millet and sorghum, are the most important crops used for fermented beverage [3]. One of these drinks is an opaque alcoholic beer-like beverage made from fermented sorghum gritz and malted maize, mainly used for rituals and festivities [4]. Two types of this beverage are produce in “Kapsiki land.” They are “tè” and “mpedli.” The first one, “tè,” also called “red kapsiki,” is the ritual beer. And the second, “mpedli,” is the “white kapsiki” beer which is mainly brewed by women for commercial purpose and has no ritual significance. “Mpedli” is made by a quick process for immediate consumption [5, 6]. The red “tè” beer in which we focus our study is traditionally a man’s brew. Its processing follows a strict procedure, with numerous prohibitions, and “red kapsiki” was for long time mainly used for ritual purposes than festivities. Symbolism was more focused on this beer rather than commercial and technical [6]. However, “red kapsiki” has increasingly become a sales commodity for women both at the village markets and in the cities as it is generally preferred by the population over “mpedli” [7, 8]. Though most of the symbolism around beer is a male-dominated discourse which concentrates on bonding and power, the symbolism is less straight forward and more hidden [6]. Despite the importance of the “red kapsiki” beer among this tribe, the beer itself remains unknown in scientific community and little is known on it processing and quality. This chapter thus aims at valorizing this opaque beer by describing its processing technique and provides some data in regard with its quality.

## 2. Materials and methods

### 2.1. Field work and sampling

In order to describe and follow the process production, a survey was conducted in three “kapsiki” rural villages of Cameroon, namely, Rhumsiki, Rhumzu, and Mogodé. Later on, some samples from one urban town close to the area Mokolo were also collected for comparison purpose. The choice of this urban area is justified by the fact that Mokolo is the immediate administrative area populated in majority by “kapsiki” populations. The sampling method used for processing description was cluster sampling [9] with two degrees of units. At the primary level, we have considered the cities surveyed, production sites and markets. At the secondary level, we have interviewed individuals and groups of individual respondents. Two layers were formed: rural area and urban area. As urban area, Mokolo was chosen because of the possibility of finding markets as well as production sites. In mountainous “Kapsiki” land, three villages were selected: Rhumsiki, Rhumzu, and Mogodé. As for the surveyed markets, we conducted a random choice in Mokolo. In the rural areas, Rhumsiki, Rhumzu, and Mogodé, all markets were taken into account because of the very limited number of markets and their periodical characters. Producers and women retailers were also randomly chosen in the areas and markets selected for the survey. A total of 15 production sites and 7 markets were visited, and 50 producers and 23 women retailers were interviewed. The interviews were conducted on the basis of a questionnaire, and collected

data were processed using the software Winstat through a counting sheet constructed from the questionnaire.

## 2.2. On-site experiment

For characterization, 40 samples of the “red kapsiki” were collected from production sites and sales points. The sample pH was measured directly onsite using a portable pH meter. The conductivity, density, and brix were also recorded onsite using portables devices conductometer, densitometer, and brix meter, respectively. Around 10 ml of each sample was introduced into test tubes and gently shaken. The probe of designated apparatus (pH meter, conductometer, and densitometer) was then deepening into the test tube, and the values were read directly on the screen of the device. The experiment was repeated four times for each sample. The mean of each read result was considered. For total soluble solids (% Brix), the refractometric method was used to determine the soluble solids in beer samples [10]. The portable refractometer was first thermostated at 20°C using boiled water and regularly calibrated with cooled distilled water until the screen of the device showed 20°C. Soluble solids were then obtained from read refractive index on device screen, by reference to a standard table.

## 2.3. Laboratory experiment

### 2.3.1. Physicochemical analysis

#### 2.3.1.1. Titrable acidity

Titration acidity (as percentage (w/w) tartaric acid) was determined according to the Association of Analytical Chemists’ method [11]. Acidity was evaluated by the alkali-potentiometric method using a 0.1-N sodium hydroxide solution in the presence of 0.4% bromothymol blue used as an indicator.

#### 2.3.1.2. Total polyphenols

Total polyphenols were assayed by calorimeter using the Folin-Dennis Ciocalteu reagent as described by Mangas et al. [12], and the results were expressed as mg/l of gallic acid.

#### 2.3.1.3. Total ethanol

Total ethanol content was preceded by a Spectrophotometric micro-method for the determination of ethanol after distillation of beer that was made alkaline by a suspension of calcium hydroxide [13].

#### 2.3.1.4. Specific density at 15°C

Specific density at 15°C was evaluated as described by Nanda et al. [14]. The specific gravity determination was done as follows: 20 ml of sample was poured into the specific gravity test

tube to overflow, then the stopper was inserted, and the whole was incubated in water bath at 200°C for 30 minutes. The test tube was removed from the water bath, wiped, and then weighed. Thereafter, the sample was boiled. The specific gravity was calculated as the ratio of weight of ash over the weight of fresh sample time 100.

#### 2.3.1.5. Volatile acidity

The volatile acidity was determined using the Mathieu method by titration of the volatile acids separated from wine by steam distillation and titration of the distillate [15].

#### 2.3.2. Microbial analysis

Around 10 ml of “red kapsiki” samples from each site was mixed with 90-ml sterile peptone physiological saline solution (1 g Peptone, 8.5 g NaCl, and 1000-ml distilled water). Decimal dilutions were prepared up to  $10^6$  from initial sample as described by Loyer and Hamilton [16]. All enumeration in solid media was carried out in triplicate, and the plates containing between 33 and 333 colonies were considered. The enumeration in liquid media was evaluated according to deMan most probable number.

##### 2.3.2.1. Total aerobic mesophilic bacteria

Total aerobic mesophilic bacteria were enumerated on Plate Count Agar (PCA-OXOID) supplemented with cycloheximide 0.5% [17]. The plates were incubated at 28°C for 48–72 hours.

##### 2.3.2.2. Total coliforms and *Escherichia coli*

Total coliforms and *Escherichia coli* were accessed on Bubble Lactose Bile with Brilliant green (BLBVB- DIFCO). The tubes containing the Durham bells were incubated at 30°C during 24–48 hours. The positives tubes were used to inoculate another test tube containing water peptone without indole and were incubated at 44°C for 24 hours for *E. coli* determination, which was revealed using Kovac’s reagent [18].

##### 2.3.2.3. *Streptococcus*

Fecal *Streptococcus* was enumerated on Slant Agar (SL-Merck) supplemented with cycloheximide at 0.5% after 48 hours of incubation at 37°C [19].

##### 2.3.2.4. *Salmonella* and *Shigella*, yeasts and molds, sulfite-reducing

- *Salmonella* and *Shigella* were analyzed as described by Ribot et al. [20].
- Yeasts and molds were enumerated on PDA-Chloramphenicol (200 g potatoes extract, 10 g peptone, 20 g glucose, 15 g agar, 0.5 g chloramphenicol, and 1000 ml distilled water, pH was adjusted to 5.2) after 48–72 hours of incubation at 30°C [18].
- Enumeration of sulfite-reducing clostridia was done according to Mossel [21] method in anaerobic jar.

#### 2.3.2.5. Total spore-forming bacteria

Total spore-forming bacteria were evaluated on GPB agar medium (10-g peptone, 2-g starch, 5-g glucose, 15-g agar, 40-mg bromocresol purple, and 1000-ml distilled water) after 10 minutes of pre-heating of the samples at 80°C [22]. Colony counts were performed after 48 hours of incubation at 35°C.

#### 2.4. Statistical analysis

Comparison of the means was performed by the ANOVA associated with Tukey's honest significant difference (HSD) test to discriminate significantly different pairs of means values. Means values were considered statistically different at  $P \leq 0.05$  significance level.

### 3. Results and discussion

#### 3.1. Traditional processing of the “red kapsiki”

Sorghum beer is generally made from grain and water, sometimes a gelatinous or mucilaginous agent [23]. In Cameroon, most of non-Islamized ethnic groups process it even in different forms. The obtained beer is named according to ethnic groups and countries. Names of beer are as follows: “Tchoukoutou” in Togo and Benin, “Pito” and “Burukutu” in Ghana and Nigeria, “Dolo” in Burkina-Faso, “Tchapalo” in Ivory Coast, “Busaa” and “Bushera” in Kenya, “Ikigage” in Rwanda, Kaffir in South Africa, “Mahewu” in Zimbabwe, “Malwa” in Uganda, “Munkoyo” in DR Congo, and “Bili-Bili” in Cameroon. **Figure 1** describes the traditional processing of “red kapsiki” beer which commonly includes the following:

##### 3.1.1. Malting

In the case of “red kapsiki,” as most of beers, the process production starts by the selection of grains. The “red kapsiki” being a noble beer, only good quality grains are considered. Mostly, the sorghum variety “mouskwari” is selected for the “red kapsiki” production. However, in raining season, “Djigari” variety can also be chosen.

##### 3.1.1.1. Quenching

After being washed, the grains are immersed in water for 12–24 hours so as to obtain a moisture content of 35–40% for germination. The temperature of water is very important: at high temperature, the quenching is rapid. The immersion temperature is close to that of room temperature (around 40–45°C in the region). The grains are first drained on tissue and then stabled in double layer on cotton cloth bags or on woven mats.

##### 3.1.1.2. Germination

The soft grains are covered and placed in dark area for 2–3 days for germination. Water is sprayed sometimes, when the ambient air is dry or when the temperature is hot. Alternatively,

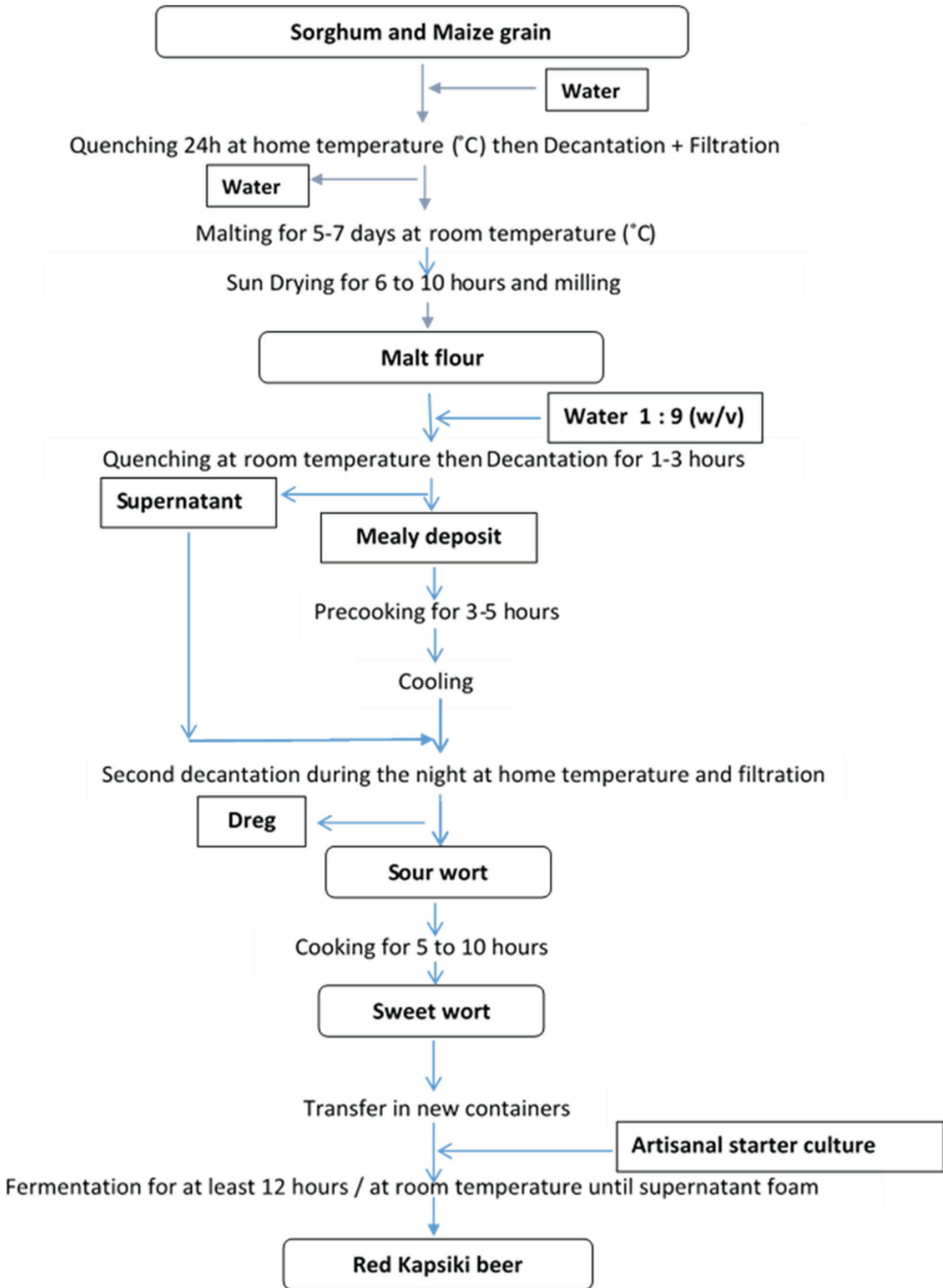


Figure 1. Technological diagram of homemade “red kapsiki” beer.

the grains are left on the ground and sprayed until the germination process starts and root-lets appear. The high temperature facilitates the beginning of germination. In this case, the germination time can last for 4 days. It should be noted that the same technique is used at the household level to improve the energy density of slurries [24]. During germination, amylolytic enzymes are produced and protein digestibility of sorghum, which is generally low, is improved [25]. It was also demonstrated that after 3 days of malting, there was production of amylolytic enzymes, including  $\alpha$ -amylase,  $\beta$ -amylase, and dextrinase, which are all essential for good quality of malt [26].

#### *3.1.1.3. Drying*

This corresponds to the "Kilning" and brings moisture to malt to keep 15–20% without mold. The malt is dried in sun for one or more days, sometimes less if the process goes straight to the brewing stage. In case of the production of special "red kapsiki," it was noticed that after malting, grains are roasted in firewood and ground coarsely. The obtained powder is kept in dark for 2 days before brewing.

#### *3.1.2. Brewing*

##### *3.1.2.1. Milling*

The previously malt is crushed in a mortar/pestle in rural sites or in a wen in urban area.

In fact, the malt is brought to a motorized milling machine sets to crushing mode, to obtain a coarse flour.

##### *3.1.2.2. Pasting*

The grind is mixed with water and a gelatinous or mucilaginous agent (okra or sap of various trees that improve flocculation and filtration of insoluble in suspension). After an hour of storage at temperature of 25 to 35°C, the mixture was separated into two phases, the upper liquid phase which is collected. The upper liquid phase already contains a soluble portion of malt sugar.

##### *3.1.2.3. The decoction*

The lower phase containing malt flour is cooked slowly to boiling so as to obtain a starch paste (slurry consistency). The upper liquid base is then mixed with a water to be more easily saccharified than if it was not being cooked, and the diastatic actions being more effective on cooked starch than on raw starch. Alternatively, like for other sorghum beer processing, where the raw grain is added [27, 28, 29], in the case of the "red kapsiki," production may continue with malted sorghum powder. In fact, ground malted sorghum is dissolved in water at the ratio of 1/9 (w/v). After 1–3 hours of soaking, supernatant is removed and kept for a later use. The remaining mealy material at the bottom of the soaking container is then removed and cooked for 3–5 hours. It must be noticed here that some enzymes produced during the malting



stage seem not digested. This may be due to the soaking temperature, which is not optimal for enzymes. The mealy deposit is constituted by 80% raw starch. This starch is cooked and lightly cooled before previously removed soaking water probably containing starch-digesting enzymes is added. The mixture is then kept warm for 1–5 hours or let stand overnight at room temperature.

#### 3.1.2.4. Filtration

After the decoction phase, the paste-like mixture previously removed becomes liquid and is filtrated. The dry matter is discarded, while the sour mash obtained is kept for the next step of the process. The filtration is mostly done through polypropylene bags, and the slurry obtained after decoction is passed through this polypropylene bag. The filtrate now called “liquid must” is kept for further processing when the drench is used as animal feed.

#### 3.1.3. Cooking

The liquid must be concentrated and clarified by skimming. This operation is stopped by several criteria: clarity, color of the must, cold consistency (syrupy appearance) and also the flavor of the must. This operation consisted of two cooking steps. The first step is a precooking of mealy deposit during 3–5 hours to produce a “sour liquid must.” The second one is a cooking of the “sour liquid must” 5–10 hours to produce a “sweetish liquid must” which is called “tè kwarhèni” in the local Kapsiki dialect.

#### 3.1.4. Fermentation

The sweetish must is cooled either spontaneously or by successive decanting and then starter culture is added. Fermentation lasts 12–24 hours at room temperature. This last step is stopped when supernatant liquid foam. The beverage obtained at the end is called “tè” or “red kapsiki.”

### 3.2. Biochemical profile of the “red kapsiki”

As presented in **Table 1** and compared to other African beer as described by Lyumugabe et al. [29], the “red kapsiki” presents a greater alcohol content (3.85–4.28% v/v). This beer seems more alcoholic than “Bushera” 0.27% [30], “Burukutu” 1.63% [31], “Munkoyo” 2.1% [32], “Dolo” 2.3% [33], “white Kapsiki” beer ( $2.48 \pm 0.14\%$ ) [34], and “Pito” (3.09%) [35]. However, the “red kapsiki” would be less alcoholic than “Tchapalo” (5.03–5.22%) [28]. We noticed a pH between  $2.40 \pm 0.19$  and  $3.26 \pm 0.03$ . With an average pH below 4.5, the “red kapsiki” beer samples would be of satisfactory quality according to the CODEX STAN 243. Soluble extract varies from 6.30 to 7.29 °P, Brix from 7.0 to 7.46 °B, and total sugar from 41.8 to 72.9 g/l. Compared with the literature, this beer seems to be sweeter than “Tchapalo” 5.3 g/l [28], “Dolo” 7.7 g/l [33], and “Pito” 34 g/l [35]. This beer has a conductivity from 1919 to 1990 ( $\mu\text{S}/\text{cm}$ ) and a specific density (g/cm) at 15°C of about 1.33. The color of the “red kapsiki” varies from a pinky brown to reddish according the variety of sorghum used. As most of African sorghum beers, the “red kapsiki” presents a touch of fruitiness added to their fermentation odor. This beer is mainly consumed

	Mogodé	Mokolo	Rhumsiki	Rhumzu
pH	2.46 ± 0.08 <sup>a</sup>	2.42 ± 0.12 <sup>a</sup>	2.40 ± 0.19 <sup>a</sup>	3.26 ± 0.03 <sup>a</sup>
Total titrable acidity (mg/l)	6.7 ± 0.4 <sup>a</sup>	8.1 ± 0.5 <sup>b</sup>	7.7 ± 0.1 <sup>b,c</sup>	7.2 ± 0.6 <sup>a,c</sup>
Soluble extract (°P)	7.28 ± 1.29 <sup>a</sup>	7.29 ± 0.26 <sup>a</sup>	7.29 ± 0.26 <sup>a</sup>	6.30 ± 1.09 <sup>a</sup>
Brix (°B)	7.0 ± 1.06 <sup>b</sup>	7.46 ± 0.83 <sup>b</sup>	7.42 ± 0.84 <sup>b</sup>	7.0 ± 0.16 <sup>b</sup>
Total ethanol (% vol)	3.85 ± 0.58 <sup>a</sup>	4.10 ± 0.46 <sup>a</sup>	4.08 ± 0.46 <sup>a</sup>	4.28 ± 0.78 <sup>a</sup>
Total sugars (g/l)	72.8 ± 1.29 <sup>a</sup>	72.9 ± 0.30 <sup>a</sup>	72.9 ± 0.40 <sup>a</sup>	41.8 ± 0.39 <sup>a</sup>
Conductivity (µS/cm)	1919.23 ± 8.12 <sup>a</sup>	1990.0 ± 4.08 <sup>b</sup>	1990.0 ± 3.53 <sup>b</sup>	1929.00 ± 4.02 <sup>a</sup>
Specific density (g/cm) 15°C	1.03 ± 0.00 <sup>a</sup>	1.33 ± 0.00 <sup>a</sup>	1.00 ± 0.00 <sup>a</sup>	1.62 ± 0.00 <sup>a</sup>

NOTE: Mean values preceded by at least one common letter (a, b, c) in the same line are not significantly different ( $P < 0.05$ ) according to the ANOVA and Tukey comparison test.

**Table 1.** Biochemical profile of the “red kapsiki” beer.

in an actively fermenting state leading to a short shelf life as mentioned for other African beer in literature [20, 29, 36, 37]. Statistical analyses carried out on the physicochemical composition of “kapsiki red” beers show generally that there is no significant difference between the samples from the different sites. Indeed, the physicochemical parameters of this beer are substantially the same from one site to another. Despite a difference in the manufacturing process, the results obtained with this beer are similar to those of Yao et al. [38], which showed a consistency in the physicochemical properties of “Tchapalo” taken from nine different sites in the city of Abidjan. At first glance, this regularity seems surprising since the artisanal production of “kapsiki red” beer is made without measuring and precision equipment. The operations are done by simple visual and sensorial appreciation [28]. This apparent invariability could be explained by the fact that manufacturing being empirical, brewers have kept the same reflexes and habits. This allows them to obtain more or less identical finished products.

As present in **Table 2**, the “red kapsiki” contains a quite good amount of polyphenols. The recorded amount varies from  $843 \pm 27$  mg/l in Mogodé samples to  $1150 \pm 27$  mg/l in Rhumzu samples. It must be noticed that some of these polyphenols are too low or absent in other “industrial” beer. As indicated by Bröhan et al. [39], when barley malt is used for mashing, around 30% of total beer polyphenols are issued from hop, although added in 100 times lesser quantity than malt. In the case of the “te” or “red kapsiki,” the sorghum contribution to beer polyphenols could be much higher. In fact, sorghum phenolic acids include hydroxybenzoic (mainly protocatechuic acid) and hydroxycinnamic acids [40, 41] both free and bound as esters. Most of them are found in usual lager beers brewed either from barley malt or from hop [42]. Sorghum anthocyanins are unique, as they lack the hydroxyl group at the 3-position of the C ring. These 3-deoxyanthocyanins such as luteolinidin and apigeninidin are used as natural food colorings because they are more stable than anthocyanidins in both organic solvents and acidic solutions. Amount of 1500 mg/l of flavonol was recorded in “red kapsiki.” Bröhan et al. [39] indicate that flavonols such as apiforol (leucoapigeninidin) and luteoforol (leucoluteolinidin) are sorghum polyphenols as precursors of sorghum 3-deoxyanthocyanins.

Sample	Volatile acidity (g/l)	Total polyphenols (mg/l)	Flavonol (mg/l)
Rhumzu	0.3 ± 0.00 <sup>a</sup>	1150 ± 27 <sup>a</sup>	1300 ± 27 <sup>a</sup>
Rhumsiki	0.2 ± 0.00 <sup>b,c</sup>	911 ± 22 <sup>b</sup>	1000 ± 32 <sup>c</sup>
Mogodé	0.1 ± 0.00 <sup>c</sup>	843 ± 27 <sup>b,a</sup>	834 ± 16 <sup>a,d</sup>
Mokolo	0.2 ± 0.00 <sup>b,c</sup>	1111 ± 32 <sup>c,a</sup>	750 ± 23 <sup>e,a</sup>

NOTE: Mean values preceded by at least one common letter (a, b, c, d, e) in the same line are not significantly different ( $P < 0.05$ ) according to the ANOVA and Tukey comparison test.

**Table 2.** Some essential biochemical compounds of the “red kapsiki”.

Never reported in beer, they have been found at concentrations up to 4200 mg/kg in sorghum [43]. Other sorghum flavonoids include the flavones apigenin and luteolin [44], the flavanones naringenin and eriodictyol [45], the flavonol kaempferol, the dihydroflavonol taxifolin, and the flavan-3-ols (picatechin and epicatechin. Hop brings similar flavonols and flavan-3-ols to wort, in industrial brewing.

### 3.3. Microbial profile of the “red kapsiki”

The results of the microbiological analysis of beers obtained are shown in **Table 3**. Analysis of these results shows that the parameters sought in the produced beers are not in accordance with international microbiological criteria [46]. The presence of pathogens as Coliforms, *Salmonella* and *Shigella*, and yeasts and molds in these beverages indicates that the “red kapsiki” is of bad hygienic quality. In fact, it’s said that one of the main factors limiting the use of the “red kapsiki” like most of African opaque beers is that they spoil rapidly due to extra bacterial action. Despite its low acidity and pH, the load of microorganisms is important (**Table 3**). Total aerobic microflora is up to  $6.2 \cdot 10^7$  cfu/ml. This may be explained by the fact that the “red kapsiki” is still actively fermenting when sold and consumed. This means that the process is not optimal yet when the beverage is consumed. The total coliform, total spore-forming bacteria, and clostridia loads are higher in Mokolo sample than in other samples, with values of  $(2.4 \pm 0.7) \cdot 10^5$  cfu/ml,  $(7.7 \pm 0.3) \cdot 10^3$  cfu/ml, and  $(3.9 \pm 0.6) \cdot 10^3$  cfu/ml, respectively. The presence of coliforms and fecal *Streptococcus* genera is obvious as the “red kapsiki” presents a too low acidity level and presence of alcohol even in insufficient amount. It was expected to have a synergetic effect of acid and alcohol against microorganisms. Among the pathogenic microorganisms could be isolated in craft beers, we can mentioned coliforms as *Escherichia coli* and spore-forming bacteria species. Their presence and persistence in these beverages would not only be linked to a simple contamination but also to their adaptation ability. Indeed, several studies have shown that some environmental parameters such as low temperatures like those that are observed during processing have the capacity to induce the resistance of these microorganisms to high temperatures [47] and strongly acidic pH [22, 48]. Bayoï et al. [22] showed that spores of *Bacillus subtilis* and *Geobacillus stearothermophilus* pre-treated at 45, 50, and 60°C during 1–3 hours before treatment with acetic acid at pH 4.5 were significantly more resistant to this acid compared to the spores of the same bacterial species non-pretreated and subjected under the identical acid conditions. Etoa and Adegoke [47]

	Mogodé	Mokolo	Rhumsiki	Rhumzu	Standards
Total count (cfu/ml)	$(6.1 \pm 0.2) 10^{5b}$	$(6.2 \pm 0.5) 10^{7a}$	$(5.1 \pm 0.3) 10^{5b}$	$(7.4 \pm 0.1) 10^{4b}$	$<10^6$
Total coliform (cfu/ml)	$(7.2 \pm 0.5) 10^{4b}$	$(2.4 \pm 0.7) 10^{5a}$	$(4.2 \pm 0.4) 10^{3b}$	$(1.4 \pm 0.3) 10^{4b}$	$<10^3$
Total thermo-tolerant coliforms (cfu/ml)	$(9.2 \pm 0.4) 10^{1a}$	$(3.1 \pm 0.4) 10^{3b}$	$(5.2 \pm 0.7) 10^{1a}$	$(3.1 \pm 0.5) 10^{2a,c}$	$<10^2$
Fecal Streptococcus (cfu/ml)	$(2.2 \pm 0.2) 10^{2c}$	$(3.7 \pm 0.4) 10^{4a}$	$(3.2 \pm 0.3) 10^{3c}$	$(2.2 \pm 0.2) 10^{4b}$	$<10^3$
<i>Salmonella</i> and <i>Shigella</i> (cfu/20 g)	$(8.1 \pm 0.7) 10^{1b}$	$(4.5 \pm 0.2) 10^{3a}$	$(9.2 \pm 0.7) 10^{2b}$	$(7.2 \pm 0.5) 10^{3c}$	Absence/20g
Sulfite-reducing clostridia (cfu/ml)	$(5.0 \pm 0.4) 10^{1b}$	$(7.7 \pm 0.3) 10^{3a}$	$(7.2 \pm 0.9) 10^{1b}$	$(2.5 \pm 0.6) 10^{2b}$	Not known
Total fungi (cfu/ml)	$(3.5 \pm 0.8) 10^{3b}$	$(3.2 \pm 0.7) 10^{5a}$	$(4.5 \pm 0.4) 10^{4b}$	$(6.1 \pm 0.2) 10^{4b}$	$<10^5$
Total spore-forming bacteria (cfu/ml)	$(2.7 \pm 0.2) 10^{2a}$	$(3.9 \pm 0.6) 10^{3b}$	$(2.4 \pm 0.2) 10^{2a}$	$(9.7 \pm 0.2) 10^{2a}$	$<10^4$

NOTE: Mean values preceded by at least one common letter (a, b, c) in the same line are not significantly different ( $P < 0.05$ ) according to the ANOVA and Tukey comparison test.

**Table 3.** Microbial profile of the "red kapsiki".

and Bayoï et al. [22] explained this phenomenon during which there was a slight increase in resistances in the spore following their stay at sublethal temperatures (heat-induced resistance), by the structural modifications of the spores molecules, mainly those of the different tunics and of the inner membrane. According to these authors, these molecules would undergo changes in conformation in presence of sublethal temperatures, which would result in the reduction of the permeability with respect to chemicals. Wang and Doyle [48] showed that survival in a minimum glucose medium at pH 2.5 of certain strains of *E. coli* pretreated at 48°C for 10 minutes was 10–100 greater compared to strains nonpretreated. According to Small et al. [49], this difference in acid resistance of pretreated *E. coli* strains could be the result of either the difference in the expression of the *rpoS* gene or the amount of synthesized heat shock proteins. Wang and Doyle [48] have clearly shown that the induction of acid resistance by thermal shock implies the synthesis of new proteins. According to these authors, two proteins, namely one of 22 kDa and another of 15 kDa, were synthesized at the outer membrane during the heat shock (48°C/10 minutes). Indeed, these two proteins would be subunits of an alkyl hydroperoxide reductase involved probably in the transport of protons out of the cell [48]. This phenomenon was called "heat-induced acid resistance" [22]. The presence of *E. coli* would also probably be related to the induction of other mechanisms associated with acid resistance in *E. coli*. Indeed, in *E. coli* more specific systems neutralize the protons entering the cell which contributes to increase the internal pH (pHi). Four systems, known as AR or "Acid Resistance," have been identified. The first, AR1 inhibited in the presence of glucose, is able

to protect the cell in stationary phase, and it is dependent on RpoS and the CRP-cAMP complex [50]. The presence of glucose in the medium reveals three other systems, AR2 (Arginine decarboxylase), AR3 (Lysine decarboxylase), and AR4 (Glutamate decarboxylase). These systems respectively decarboxylate arginine, lysine, and glutamate in agmatine, cadaverine, and  $\gamma$ -aminobutyrate (GABA), which are expelled into the outside environment. This allows the consumption of a proton ( $H^+$ ) and the release of  $CO_2$ . Thus, when the external pH is 2.5, these decarboxylations allow the increase of the internal pH of 3.6 to 4.2–4.7, and the inversion of the membrane potential, essential for the survival of *E. coli* [51].

Indeed, studies on traditional sorghum beer in West Africa show that these drinks are a complex biotope composed of several genera and species of microorganisms dominated by yeast [29, 52, 53]. Their prevalence is probably because they are added by inoculation of the traditional starter in the sweet wort to ensure alcoholic fermentation [38, 54]. During fermentation, we initially have a yeast growth which is accompanied by the production of ethanol after the logarithmic growth phase, and which continues during the stationary phase. It has been observed that during this time, very little or no increase in the number of contaminating organisms seems to occur [18]. However, the presence of yeast in beer would also be due to adaptation in response to the accumulation of ethanol produced. According to Dombek and Ingram [55], this adaptation was accompanied by a change in the composition of membrane lipids after accumulation of ethanol. This changes in the composition and structure membrane would allow the yeasts to escape at the solubilizing action of ethanol. The surviving yeasts can readily begin another post-adaptation growth cycle. The isolated pathogenic bacteria can originate from the environment, the raw material, and the equipment used. The hygienic quality of beer produced depends closely on the conditions of fermentation of the must. Indeed, the levels of total sugar and vitamin C are relatively high in beers obtained from the fermented mash. The recorded values for the “red kapsiki” are higher than those in the “Tchapalo” [28, 54] where the fermentation is carried out at a room temperature with a starter culture based on previous productions. It must also be noticed, to explain the prevalence of pathogens, that after few days of fermentation, the amount of yeasts decreases because of autolysis. With little or no competition from yeasts for the readily available nutrients, contaminating microorganisms increase rapidly in number and their metabolites may change and spoil the beer. Because of the relatively high temperature of the “red kapsiki” fermentation, these sequential events occur within a short-time period. This period does not usually exceed more than 3 days in summer or 5 days in winter before this spoilage occurs. The metabolic activities of mesophilic bacteria are primarily responsible for the spoilage. These bacteria, along with other undesirable bacteria, may produce acetic acid, volatile off-flavors, fruity odors, and pellicles which render the taste, odor, and texture of the beer unacceptable to consumers.

## 4. Conclusion

The color of the “red kapsiki” is pink brown to reddish according the variety of sorghum used. This artisanal beverage requires steps of malting, quenching, germination and “kilning,”

decoction, filtration, boiling and sterilizing, cooling, sowing, and fermentation for its production. The “red kapsiki” presents an interesting physicochemical profile, but has a high degree of microbial contamination for consumption, and we noticed the presence of pathogens such as coliforms, *Salmonella*, *Shigella*, as well as some alteration flora as yeasts and molds. The potential of the beverage for sales and income adds to the fact that this beverage has symbolic value for local population and there is a need to improve its entire process production and hygienic quality. Thus, for the advanced knowledge about certain characteristics of this local beer, it appears necessary to include in future studies a hazard analysis critical control point (HACCP) in order to propose a better manufacturing technology to ensure the production of a good hygienic “red kapsiki” beer.

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