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Research Article

Nutritional and Functional Valorization Local Traditional Beverages in Cote D'Ivoire: Case of Sorghum Sweet Wort

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Abstract

In Côte d'Ivoire, the local traditional sorghum beer and sorghum sweet wort were very popular. This might rested on eventual therapeutic virtues attributed by consumers. To date no *in vivo* study focused on health benefits of sorghum sweet wort have been carried out. The aim of this research work was to study nutritional and functional potentialities of sorghum sweet wort. Thus, the macronutriments, micronutriments, phenolic compounds content, antioxidant activity, of sorghum sweet wort samples were analyzed. Also weigt gain and haematological parameters of mice after sorghum sweet wort samples were investigated. Results revelaed that the energy value of sorghum sweet wort from Koumassi (SSK) was higher with 36.84±0.2 Kcal/100 mL than this of Yopougon (SSY) with 27.96±0.02 Kcal/100 mL. Regarding phenolic compounds the values of total phenol and total flavonoids contents were highest in SSK sample with 1.239±0.09 mg/mL EAG and 1.810±0.09 mg/mL EQ respectively. In contrast, condensed tannins content was more important in SSY samples (0.271±0 mg/mL EC) than in SSK samples (0.125±0.01 mg/mL EC). Also, the antioxidant activity was most highed in SSY sample with 82.12±0.01 % than in SSK samples with 78.50±0.01%. The weight gain of mice was more with SSK sample than SSY samples with 82.22% and 40.42% respectively. On the hand other, the sorghum sweet wort samples consumption had not affected the relative organ weight and haematological parameters of mouses which were complies to standards. At nutritional point view, SSK sample seemed the most suitable in diets regime.

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Keywords

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1. Introduction

Sorghum (*Sorghum bicolor*) have a crucial in safety in many regions of Africa. Its involvement was reported in many foods cookig such as breads, porridges, pastes and pancakes [1]. However, in several countires of sub-saharan Africa those the Côte d'Ivoire, sorghum was most used to prepare a beer [2]. Thus, where sorghum is produced, it is also abundantly used to prepare traditional beers commonly named sorghum beers or opaque beers but known as pito or burukutu in Nigeria, chibuki, in Zimbabwe, dolo in Mali and Burkina Faso, bili bili in Chad and tchapalo in Côte d'Ivoire [2, 3]. The success of this local beer was largely due to therapeutic virtues attributed by the consumers. Also, it is involved in cooking of many foods. On the hand other from its composition biochemical and nutritional, sorghum has been reported as plant with medecinal virtues by numerous authors [4]. These latter have involvement of sorghum in several deseases treatment. Moares et al. [5] reported that sorghum involvement in improves glucose tolerance, insulin resistance and preserved pancreatic islets function in obesity diet-induced rats. Also, Silamlak [6] had claimed that the sorghum possesses potentialities benefits on human health namely lowering hypertension, antioxidant activity, cancer deterrence, obesity and inflammation preventions, dyslipidemia and cardiovascular disease prevention, anti-diabetic activity. Sorghum grain has the highest level of phenolic compound antioxidant activity when compared to other cereal grains. Antioxidant activity and total phenolic levels more especially, condensed tannins have a strong relationship [7]. Food's chemical load is decreased when natural antimicrobials are used [8]. Rajendran [9] reported that it had antibacterial action against *S. aureus* and *E. coli*. According to traditional medicine, sorghum's red pigment has antibacterial and antifungal qualities and is used to treat anaemia [10]. Phenolic extract from sorghum is a natural antibacterial substitute that works well and has been shown to have several medical advantages [4]. Phenolic acids and flavonoids, two bioactive compounds that target multiple cancer symptoms, are linked to sorghum's anti-cancer properties. Among other polyphenols, sorghum contains tannins, policosanols, anthocyanins, phytosterols, and phenolic acids. Black sorghum's 3-deoxy anthocyanins have anti-inflammatory and anti-tumor properties. Flavones with estrogenic characteristics found in sorghum have been shown to have anticancer effects *in vitro* [11]. Sorghum provides benefits against obesity. According to Ofosu et al. [12], sorghum extracts are essential for the lipid metabolism of pancreatic lipase enzymes and prevent the accumulation of triglycerides. Consuming extruded sorghum was observed to encourage weight loss, as well as lower waist circumference and body fat percentage [13]. Several phenolic compounds found in sorghum have the ability to prevent the synthesis of these pro-inflammatory molecules [14]. Together with extracts from cowpea and sorghum that are rich in quercetin, flavone apigenin and flavanol quercetin have strong synergistic anti-inflammatory properties that increase their bioavailability in cells. Again, anaemia, pain, and inflammation are all treated with sorghum in Lagos, Nigeria [15]. Sorghum is utilized as an aphrodisiac in India. Sorghum grain decoction is used to treat renal and urinary tract symptoms because it is demulcent and diuretic. Sorghum is used as a treatment for headache, sickle-cell anaemia, leukaemia, multiple myeloma, cardiac difficulties, and blood-related issues in South Western Nigeria. Some scientific research suggests that sorghum may be used as an antidiarrheal medication [4]. By preventing long-term illnesses like nitric oxide (NO), synthetase, and xanthine oxidases, as well as by lowering inflammation in conditions like cardiovascular diseases, tannins can improve human health. Moreover, they inhibit prooxidative enzymes [16]. Regarding, this latter, Ofosu et al. [12] showed that fermented sorghum enhanced type 2 diabete remission by modulating gut microbiota. The process of beer preparation included two fermentations: lactic fermentation carried out by lactic acid bacteria which is spontaneous fermentation and produced the sorghum sweet or sorghum wort. The second fermentation is alcoholic fermentation performed by yeasts with alcohol production. Also, sorghum beverages could varied greatly from brewer to brewer because composition and nature of microorganisms responsible of the fermentation. Even, beer remains the main product of sorghum transformation, another derived-beverage from lactic acid fermentation was apprecited namley sorghum sweet. This beverage was characterized by a sugared taste and free-alcohol and was appreciated by women and children [1]. Globally, essential researchs on sorghum beverages were focused on sorghum beer. Traditional sorghum process enhancement was studied by Adewara and Ogunbanwo [17] and Coulibaly et al. [1-18]; nutritional values of sorghum beer was investigated by Aka et al. [19] and bioactive compounds composition of sorghum beer was determined by Coulibaly et al. [15]. Few research works were focused in sweet wort. Thus this study aimed to investigate nutritional and functional potentialities of sweet sorghum.

2. Material and Methods

2.1. Sampling

The sweet sorghum samples were collected to Yopougon and Koumassi, two communes of District of Abidjan. For each site, three (3) samples of 1 Liter were collected. These sites have been choosen because their popularity and numerous beermakers and cabarets.

2.2. Physicochemical Analysis

The samples' physicochemical properties, including their moisture, fat, protein, fibre, ash, and minerals, energy value and carbohhydrate were examined.

2.2.1. Mositure

The samples were then weighed after cooling in desiccators. The weight loss was calculated as a percentage (%) of the samples' initial weight to determine their moisture content.

2.2.2. Ash

The AOAC [20] technique was used to determine the ash content. Ten grams (10 g) of the sample was weighed into a porcelain crucible that had already been dried and weighed. The crucible and its contents were placed in a 550 ℃ furnace for twelve (12) hours. The crucible and its contents were weighed after cooling in desiccators. The ash's weight was represented as a percentage (%) of the sample's initial weight.

2.2.3. Fat

The AFNOR method [21] was used to determine the fat content by using soxlhet equipment and and the weight of fat extracted divided by the sample weight multiplied by 100 was used to calculate the percentage of fat.

2.2.4. Protein

Protein content was determined by using the Kjeldahl method [20]. A conversion factor of 6.25 was used to calculate the percent total nitrogen and crude protein.

2.2.5. Fiber

The AOAC [20] method was used to determine the dietary fiber content in the samples. The residue obtained was incinerated in an oven at 550 ℃ for three (3) h and cooled in a desiccator and the ash weighed.

2.2.6. Mineral

The determination of minerals was carried out according to the method by Kularatre and Fretas by using the atomic absorption spectrophotometer equipment [22].

2.2.7. Total Carbohydrate Content and Energy Value

Carbohydrate content have been determined based on the contents of other biochemical compounds.

$$\mathrm{C}(\%) = [100 - (Protein + Fat + Ash + Moisture] \quad (1)$$

2.2.8. Energy Value

$$\mathrm{EV}\ \ (\mathrm{Kcal}/100\mathrm{gDM}) = (4XC) + (4XP) + (9XF) \quad (2)$$

2.2.9. Phytochemical Analyses

(i). Total Phenols

The Folin-Ciocalteu reagent was used in Singleton et al.'s colorimetric approach to measure total phenols [23]. After centrifugation, 250 µL of the diluted Folin-Ciocalteu reagent (10% v/v) was applied to a 50 µL aliquot of the finished result. Following a minute, 750 µL of aqueous Na_2CO_3 (20% w/v) was added, and the volume was then adjusted to 5.0 mL with water. All reaction reagents were present in the controls, with the exception of the sample. The absorbance was measured at 760 nm after two hours of incubation at 25 ℃. Controls and a calibration curve for gallic acid were used as comparisons. To assess total phenols in gallic acid equivalents per millilitre, the average of three replicate analyses is used to report the data.

(ii). Condensed Tannins

The determination of condensed tannins in the samples was carried out according to the method described by Heimler et al. [24]. To 400 µL of each sample, 3ml of a 4% methanolic vanillin solution and 1.5 ml of concentrated hydrochloric acid were added. The mixture is incubated for 15 min and the absorbance is read at 500nm. The concentrations of condensed tannins are deduced from the calibration ranges established with catechin (0-300µg/ml), and are expressed in µg of catechin equivalent per mg of extract.

(iii). Total Flavonoids

The total flavonoid concentration has been determined by the $AlCl_3$ colorimetric method, as described by Meda et al. [25]. A 0.5 mL sample was combined with equal parts of sodium acetate (1 M), aluminium trichloride ($AlCl_3$) 10% (w/v) (Labosi, Paris, France), and water (2 mL). Using a Rayleigh spectrophotometer (UV spectrophotometer; Rayleigh, New-York, USA), the absorbance at 415 nm was measured following a 30-minute incubation period at room temperature. With the help of a 0-300 g/mL quercetin calibration curve (Sigma-Aldrich Chemie, Steinheim, Germany) and the mean value of three repeats, the total flavonoid contents were determined as g of quercetin equivalents (QE)/mL.

(iv). Antioxidant Activity

To determine the antioxidant properties of sweet srghum samples, their capacity to scavenge free radicals is assessed in the presence of an alcoholic solution of DPPH, which produces the free radical form DPPH° [26]. The components were combined in a methanol solution with the stable DPPH radical. Two (2) mL each of the sample and a 100 mM DPPH radical solution in methanol were added to the reaction mixture. When DPPH comes into touch with an antioxidant that has the ability to liberate hydrogen, it transforms. Hues ranging from vivid yellow to deep violet. After 30 minutes of reaction time, the colour changes were measured as absorbance (Abs) at 517 nm using a Rayleigh UV spectrophotometer manufactured in the United States. The following formula was used to calculate the rate of scavenging activity (AA%):

$$AA\ (\%) = [(X-Y) / X] \times 100 \quad (3)$$

X: the absorbance of pure, unreacted oxidized DPPH at 517 nm.

Y: the sample's absorbance following a 30-minute DPPH incubation.

2.3. Nutritional Test on Mice

2.3.1. Animal Experiments on Mice

This study was carried out on female albino *Mus musculus* mouse aged 4 to 6 weeks and weighing 13.5 ± 3 grams. The mice were reared at the Nagui Abrogoua University animal house (Abidjan-Côte d'Ivoire) and fed with pellets manufactured by Ivograin.

2.3.2. Experimental Conditions

All experiments were conducted in accordance with internationally accepted principles for laboratory animals. The use and care of the animals was in accordance with European Community Directives (EEC Directive 1986; 86/609/EEC). The animals were housed in plastic cages. The average temperature of the room was 27 ± 2 ℃ and there was an alternation of 12 h of light and 12 h of darkness. After an acclimatisation period of one week, the mice were subjected to the treatment with the exception of the control batch. For this study, 15 female albino *Mus musculus* mice were used and divided into three (3) batches of five (5) mice as follows:

1) Batch (T0) (control) gavaged with distilled water
2) Batch 1 received Koumassi sweet must by gavage at a dose of 1 mL/kg body weight.
3) Batch 2 received Yopougon sweet must by gavage at a dose of 1 mL/kg body weight.

The sweet sorghum was administered as a single daily dose over a period of 21 days. The mouse were weighed every three (3) days to assess the variation in body weight, the remaining IVOGRAIN food was weighed every three (3) days to determine the quantity of food ingested [27], the faeces were also weighed to observe the digestibility of the samples administered. At the end of the experiments, the animals were sacrificed for blood and organ sampling.

2.4. Collection and Processing of Blood Samples

At the end of the experiments, the animals were fasted for 16 hours [28]. The following day, they were anaesthetised with 10% chloral, at a rate of 3 mL/Kg, and then sacrificed. Blood samples were taken in the morning between 8am and 10am. Approximately 5 mL of blood was collected in tubes. Two types of test tube were used for the samples: violet tubes containing EDTA (Ethylenediamine tetra acetate), an anticoagulant, for the CBC (blood count) and orange tubes containing no anticoagulant for the biochemical analyses. After laparotomy (surgical opening of the abdomen), mouse organs such as the heart, liver, kidneys and spleen were carefully removed, rinsed with NaCl 9 ‰ and then weighed.

2.5. Statistical Analyses

The statistical differences ($P<0.05$) between the samples and the parameters measured were verified with ANOVA using XLSTAT software version 2016.02. The means were compared using the tukey test at a significance level of 5%. Principal component analysis (PCA) was performed using XLSTAT in order to visualize relationships among variables represented by sorghum sweet wort compounds, relative organ weight of mouses, haematological parameters of mouses.

3. Results

3.1. Biochemical Composition of Sorghum Sweet Samples

The biochemical composition of sorghum sweet samples from the communes of Yopougon and Koumassi was presented in Table 1. In general, a significant difference ($P<0.05$) was observed between the sorghum sweet samples. The sorghum sweet (SSK) produced in Koumassi was characterized by higher levels of protein, phosphorus (P), magnesium (Mg), iron (Fe), ash, dry matter, energy value and carbohydrate. Values were 0.37±0% protein, 315±0 g/Kg phosphorus, 137.32±0 g/Kg magnesium, 12.71±0 g/Kg iron, 0.19±0.01% ash and 9.40±0.03% dry matter, 36.84±0.2Kcal /100 mL energy value and 8.84±0% carbohydrate. The Yopougon sorghum sweet (SSY) was characterized by higher concentrations of vitamin C (1.5±00 mg/100 mL) and crude fibre (0.085±0%).

Table 1. Biochemical composition of sorghum sweet samples.

	Carbohydrate (%)	Proteins (%)	Fat (%)	Crude fibres (%)	Mositure (%)	Dry Matter (%)	Energy value (Kcal/100 mL)	Ash (%)	Mg (g/Kg)	Fe (g/Kg)	P (g/Kg)	Vitamin C (mg/100mL)
SSY	6.65±0^{b}	0.34±0^{b}	-	0.085±0^{a}	92.87±0^{b}	7.125±0^{b}	27.96±0.02^{b}	0.13±0^{b}	128.56±0^{a}	6.29±0^{a}	305±0^{a}	1.5±0^{a}
SSK	8.84±0^{a}	0.37±0.01^{a}	-	0.020±0^{b}	90.59±0^{a}	9.40±0,03^{a}	36.84±0.2^{a}	0.19±0.01^{a}	137.32±0^{b}	12.71±0^{b}	315±0^{b}	1.25±0^{b}

The values obtained are averages ± standard deviations determined in three trials. In the same column for each parameter, values bearing the same letter are not significantly different at the 5% threshold. SSK: sorghum sweet from Koumassi; SSY: sorghum sweet from Yopougon

3.2. Phenolic Compounds Content and Antioxidant Activity of Sorghum Sweet Samples

The phenolic compounds content of sorghum sweet samples and antioxidant activity were consigned in Table 2. The total flavonoid and condensed tannin contents were higher in the sorghum sweet samples from Yopougon (SSY). The values were respectively 2.320 ±0.25 and 1.810 ±0.002 mg/mL EQ for SSY and SSK for total flavonoids and 0.271 ±0.002 mg/mL EC of tannins for the SSY sample and 0.125 ±0.01 mg/mL EC of tannins for the SSK sample. Furthermore, a significant difference ($P<0.05$) between the samples was observed. In contrast, the total phenol content was higher in the SSK sample with 1.239 ±0.09 mg/mL EAG compared to 1.071 ±0.08 mg/mL EAG. However, statistical analysis showed no significant difference ($P>0.05$) between the samples. The antioxidant activity of the sorghum sweet samples shown that the sorghum sweet from Yopougon (SSY) has greater antioxidant activity than that from Koumassi (SSK). The values were 82.12 ±0.01% for the SSY sample compared with 78.50 ±0.01% for the SSK sample.

Table 2. Phenolic compounds content and antioxidant activity of sorghum sweet samples.

	Total phenol (mg/mL EAG)	Total flavonoids (mg/mL EQ)	Condensed tannins (mg/mL EC)	Antioxidant activity (%)
SSY	1.071±0.08^{a}	2.320±0.25^{a}	0.271±0^{a}	82.12±0.01^{a}
SSK	1.239±0.09^{a}	1.810±0.09^{b}	0.125±0.01^{b}	78.50±0.01^{b}

The values obtained are averages ± standard deviations determined in three trials. In the same column for each parameter, values bearing the same letter are not significantly different at the 5% threshold. SSK: sorghum sweet from Koumassi; SSY: sorghum sweet from Yopougon

3.3. Behaviour of Mouses After Treatment with Different Sorghum Sweet Wort Samples

Administration of the different sweet wort of *Sorghum bicolor* from Koumassi (SSK) and Yopougon (SSY), from the lowest dilution to the highest (stock solution) did not cause any behavioural changes in the treated animals compared to the control batch. No mortality was recorded during the 21 days of treatment and observation. During the experiment, no cases of loss of vigilance, breathing disorders, convulsions or coma were recorded. No alteration in locomotion or piloerection was observed during treatment. Examination of the faeces did not reveal any diarrhoea during the experiment. In short, all the animals were in good health.

3.4. Effect of Administration of Different Sorghum Sweet Wort Samples on Anthropometric Parameters

3.4.1. Effect on Food Consumption

Table 3. Average quantity of feed consumed per day for each batch.

Batch	Average quantity of feed consumed per day
Control (water)	14.05 ± 3.39^{b}

Batch	Average quantity of feed consumed per day
SSK	12.57± 2.01[a]
SSY	12.9± 3.97[a]

The values obtained are averages ± standard deviations determined in three trials. In the same column for each parameter, values bearing the same letter are not significantly different at the 5% threshold. SSK: sorghum sweet from Koumassi; SSY: sorghum sweet from Yopougon

Oral administration of the sorghum sweet wort collected at Koumassi (SSK) and Yopougon (SSY) resulted in a reduction in food consumption of 12.57 g/d and 12.9 g/d respectively, compared with 14.05 g/d for the control. In addition, a significant difference in the quantity of food consumed was observed between the samples and the control (Table 3). The mouses which drank the sorghum sweet wort samples has consumed a low amout of food than those which consumed distilled water (Control).

3.4.2. Effect on Changes in Body Weight Gain

For mouses treated with Koumassi sorghum sweet wort (SSK) and Yopougon sorghum sweet wort (SSY), the results in Table 4 indicated that at the beginning of the experiment, the body weight of animals in all groups was homogeneous before the daily administration of the different sorghum sweet wort samples. During the 21 days of the experiment, an increase in the body weight of all mouses was recorded. The body weight gain of the control mice varied from 24.02% (day 3) to 40.32% (day 21) during the experiment. The weight gain of the treated mouses was significant ($p > 0.05$) during the 21 days of treatment with Koumassi sorghum sweet wort sample (SSK), with a gain of 82.22% (day 21) compared with that of the control group.

However, for animals treated with Yopougon sorghum sweet wort (SSY), no remarkable difference in weight gain was found between treated (40.42%) and control (40.32%) animals.

Table 4. *Changes in body weight of mouse after administration of sorghum sweet wort.*

Bacth	Average weight ± Standard deviation on the average of the animals (g)/ Percentage weight gain (%) in brackets							
	Weight initial (g)	Day 3	Day 6	Day 9	Day 12	Day 15	Day 18	Day 21
Control	10.67±0.58[a]	13.23±1.15[a] (24.02)	13.45±3.21[a] (26.10)	13.45±0[a] (26.10)	13.45±1[a] (26.10)	13.71±1[a] (28.55)	14.09±1.73[a] (32.11)	14.97 ±2.085[a] (40.32)
SSK	10.67±1.15[a]	11.32±1.53[b] (6.11)	12.02±1.15[a] (12.67)	14.40±1.54[a] (35)	16.06±1.73[b] (50.56)	16.71±2.31[b] (56.67)	17.42±2.08[b] (63.33)	19.13±2.08[b] (82.22)
SSY	10.67±1.15[a]	13.36±1[a] (25.56)	13.61±0.58[a] (27.64)	13.63±0.58[a] (27.78)	13.85±1[a] (29.86)	14.52±1.54[a] (36.11)	14.77±0.58[a] (38.47)	15±1[a] (40.42)

The values obtained are averages ± standard deviations determined in three trials. In the same column for each parameter, values bearing the same letter are not significantly different at the 5% threshold. Control: Distilled water; SSK: sorghum sweet from Koumassi; SSY: sorghum sweet from Yopougon

3.4.3. Effect on Changes in Relative Organ Weights

Oral administration of SSK and SSY samples showed that the relative organ weights (heart, lungs, liver, spleen and kidneys) of treated mice did not varied significantly ($P > 0.05$) from those of mouses in the control group (Table 5). The heart weights were ranged between 0.47 ±0 and 0.54 ±0.02 g for control and SSK sample. Regarding the lungs, the weights were 1.42 ±0.15, 1.22 ±0.22 and 1.17 ±0.07 g respectively for control, SSK and SSY. The mouses which consumed water (control) exhibited liver weight of 2.19 ±0.68 g while those which consumed the SSK sample had a liver of 2.26 ±0.01 g against 2.25 ±0.01 g those which drank SSY sample. The weights of spleen of mouses which consumed water, SSK sample and SSY sample were respectively 0.2 ±0 g; 0.205 ±0 g and 0.206 ±0 g. The relative weight of kidneys of mouses were comprised between 0.45 ±0 g for control and 0.47 ±0 g for SSK sample.

Table 5. Effect of sorghum sweet wort samples on the relative organ weights.

	Relative organ weights (g)				
	Heart	Lungs	Liver	Spleen	Kidneys
Control (water)	0.47±0[a]	1.42±0.15[a]	2.19±0.68[a]	0,2±0[a]	0.45±0[a]
SSK	0.54±0.02[a]	1.22±0.22[a]	2.26±0.01[a]	0.205±0[a]	0.47±0[a]
SSY	0.48±0.06[a]	1.17±0.07[a]	2.25±0.01[a]	0.206±0[a]	0.46±0[a]

The values obtained are averages ± standard deviations determined in three trials. In the same column for each parameter, values bearing the same letter are not significantly different at the 5% threshold. Control: Distilled water; SSK: sorghum sweet from Koumassi; SSY: sorghum sweet from Yopougon

3.5. Effect of Different Diets of Different Sorghum Sweet Wort Samples on Haematological and Leukocyte Parameters in Mouses

The results of the erythrocyte and leucocyte parameters shown in Table 6. On the blood count (CBC) of the mouses, all samples induced a slight increase concentration on haemoglobin conccentration, on the red blood cell (erythrocyte) and, on white blood cell (leukocyte) compared with the control values. The results revealed that the different sorghum sweet wort diets had no significant effect ($P > 0.05$) on haemoglobin conccentration, on the red blood cell (erythrocyte) and, on white blood cell (leukocyte) for the samples. The values of erythrocyte for all samples and control were ranged (8.96 ±0.14) 10^6/µL for the control and (9.76 ±0.40) 10^6/ µL for SSY samples which which complies with the standard whose the value is (7-12,5) 10^6/µL. A slight increase in red blood cell levels in the treated animals compared with the control had been recorded. The same observation has been done for white blood cell (leucocyte). The values of leukocyte were comprised between (7.21 ±0.25) 10^3/µL for control and (7.74 ± 1.12) 10^3/µL for SSY sample. These values were complies with the standard (6-15) 10^3/µL. The haemoglobin concentration has knwon a slight increase as erythrocyte and leucocyte concentrations which increased from control to samples. The concentrations of haemoglobin were 14.20 ±0.3 g/dL for control, 14.70 ±0.35 g/dL for SSK sample and, 14.97 ± 0.58 g/dL for SSY sample. Mean corpuscular volume (MGV), Mean corpuscular haemoglobin content (MCHC), Mean haemoglobin concentration (MHC) and, reticulocyte showed no significant difference ($P>0.05$) for the different sorghum sweet wort regimes.

Table 6. Effect of sweet sorghum sweet wort samples on haematological and leukocyte parameters, 21 days after treatment of mouses.

Haematological and leukocyte parameters	Control (water)	SSK	SSY	Standard Values (Bondonny, [29]) (Keeble et al. [30]) (Boussarie, [31])
Erythrocyte (10^6/µL)	8.96±0.14[a]	9.10±0.18[a]	9.76±0.40[a]	(7-12.5)10^6
Haemoglobin (g/dL)	14.20±0.3[a]	14.70±0.35[a]	14.97±0.58[a]	10.2-16.6
Leukocytes (10^3/µL)	7.21±0.25[a]	7.52±0.90[a]	7.74±1.12[a]	(6-15)10^3
MGV (µm^3)	55±2.65[a]	54.97±0.57[a]	52.40±1.11[a]	31-62
MCHC (pg)	15.87±0.57[a]	15.23±0.38[a]	15.30 ±0.1[a]	14.7-16.8
MHC (g/dL)	28.83±0,49[a]	27.73±0.47[a]	29.27±0.42[a]	2.87-32.1
Reticulocyte (%)	2.35±0.18[a]	2.73±0.08[a]	1.86±0.25[a]	0.3-2

The values obtained are averages ± standard deviations determined in three trials. On the same line for each parameter, values bearing the same letter are not significantly different at the 5% threshold ($p >0.05$).
SSK: Koumassi sorghum sweet wortt; SSY: Yopougon sorghum sweet wort.
MGV: Mean corpuscular volume; MCHC: Mean corpuscular haemoglobin content; MCHC: Mean haemoglobin concentration

3.6. Principal Component Analysis

Principal component analysis was performed on the fourteen measured parameters, and the results were reduced down to two principal components (F1 and F2). The first primary component, F1, accounted for 61.98% of the observed variations, while the second component, F2, accounted for 38.02%. Together, F1 and F2 explained 100% of the total variance. The variables with the highest significant contributions to the two axes, F1 and F2, had coefficients with absolute values greater than 0.8 (Table 7). As shown in Figure 1, the distribution of sorghum sweet wort samples and control along the F1 and F2 axes allowed them to be classified into three groups. The first group consisted of control which fell into half right of the biplot while the second group SSY sample fell into the bottom half left of the biplot. The fird group which consisted of SSK sample fell into upper left of the biplot.

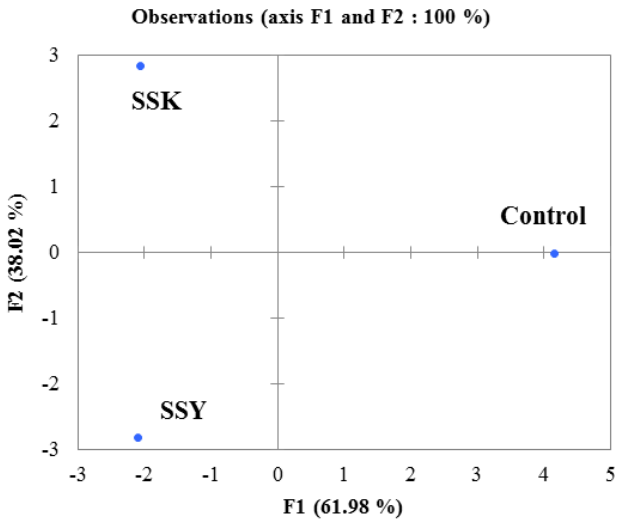

Figure 1. *Plot of the two principal components in PCA of sorghum sweet wort samples and control.*

Table 7. *Rotated principal component loading resulting from principal component analysis for mouses after sorghum sweet wort samples and control consumptions.*

	F1	F2
Average quantity of feed consumed per day	0,976	-0,218
Weight gain	-0,497	0,868
Heart	-0,605	0,796
Lungs	0,983	0,183
Liver	-0,990	0,138
Spleen	-0,989	-0,150
Kidneys	-0,863	0,505
Erythrocyte	-0,640	-0,769
Haemoglobin	-0,940	-0,340
Leukocytes	-0,913	-0,408
MGV	0,514	0,858
MCHC	0,994	-0,106
MHC	0,235	-0,972
Reticulocyte	0,079	0,997

4. Discussion

The popularity of sorghum sweet wort was due to therapeutic virtues attributed by consumers [15]. However, the lack of scientific data makes it difficult to accept such claims. This research study focused sorghum sweet wort was a contribution to valorization of local traditional beverages from plant in Côte d'Ivoire. Thus, in this study the mouses which drank the sorghum sweet wort samples shown an important weight gain than control for a low amount of food consumed. This observation could be due to the nutriments contained in sorghum sweet wort samples. In according, [4], sorghum grain, raw material used in sorghum sweet wort and traditional sorghum beer, sorghum was recognized for its high nutritional value. [32] reported that sorghum contained macronutriments (carbohydrates, protein, fat, fiber), mineral (calcium, potassium, magnesium, phosphorus) and, vitamins (niacin, riboflavin, thiamin, vitamin B and E). In this work research, the difference observed between nutritional values of sorghum sweet wort samples (SSK and SSY) could be due to process of production. Although the production process is broadly similar, variations may exist depending on the ethnic group of the brewers. [33] reported that several ethnic groups were involved in sorghum sweet wort and local traditional sorghum beer in Côte d'Ivoire. More, the samples were collected from aeras. The important nutritonal value recorded in sorghum sweet wort samples particularly in SSK sample level than in SSY sample was confirmed by the weight gain rate which was of 82.22% for SSK sample against 40.42% for SSY samples. Additionally, principal analysis component revealed the difference between the sorghum sweet sorghum samples. On the hand other, the therapeutic virtues attributed to sorghum sweet wort would be due to biactive compounds namely phenolic compounds which were responsible of antioxidant activity [34]. It's likely that the sorghum cereal used in the brewing of sweet wort and sorghum beer contributes to their medicinal properties. In fact, [35] demonstrated that sorghum's high concentration of phenolic compounds which are known to have antioxidant properties set it apart from other cereals used in breweries. Moreover, many studies have shown a strong link between total phenols and antioxidant ability [15-37]. Regarding, the relative organ weights of mouses, the sorghum sweet wort samples consumption have not influenced signficantly the organ weights

despite a slight increase of these latters. This slight increase of organ weights seemed simultaneous to weight gains of mouses. This observation would confirmed of high nutritional value of sorghum sweet wort. Also, the sorghum sweet wort samples consumption had increased slight the haemotoligical parameters of mouses particularly erythrocyte, haemoglobin and, leukocytes rate which were complies to standards. Thus, our fndings would confirmed involvement of sorghum in anaemia prevention and tretment. In according [10], sorghum was used to treat aneamia in traditional medecine. On the hand other, Tanwar et al. [4] claimed that the sorghum haved remedial importance. Antioxidant activity important of sorghum was due to phenolic compounds particularly to condensed tannins [7]. For these authors, tannins would be used in chronic deseases prevention, in reducing of inflammation. [38] reported that sorghum's low glycaemic index may be caused by the presence of condensed tannins. Possible reason for sorghum's potential to prevent diabetes: condensed tannins. The properties antimicrobial, anti-obesity, anti-cancer, anti-atherosclerotic, anti-inflammatory and, antidiarrheal of sorghum would related to phenolic comopounds [4]. Higher levels of antibacterial and anticarcinogenic abilities are also attributed to increases in phenolic compounds. Highly active phenolic compounds can be extracted from fresh sweet sorghum stalks using a technique that combines ion precipitation and acidic ethanol extraction [39]. Phenolic acids and flavonoids, two bioactive compounds that target multiple cancer symptoms, are linked to sorghum's anti-cancer properties. Among other polyphenols, sorghum contains tannins, policosanols, anthocyanins, phytosterols, and phenolic acids. Flavones with estrogenic characteristics found in sorghum have been shown to have anticancer effects *in vitro* [11]. Sorghum provides benefits against obesity. According [12], sorghum extracts are essential for the lipid metabolism of pancreatic lipase enzymes and prevent the accumulation of triglycerides. By restricting and controlling the synthesis, absorption, and excretion of cholesterol, sorghum lipids and phenolics lower the risk of cardiovascular desaeses. A crucial enzyme in the synthesis of cholesterol, 3-hydroxy-3-methyl-glutaryl-coenzyme A (HMG-CoA) reductase, is inhibited by lipids derived from sorghum [40]. Consuming hydrophobic sorghum extracts decreased plasma non-HDL cholesterol and the hamsters' ability to absorb cholesterol, as shown by [41]. According [14], sorghum is rich in phenolic compounds that have the ability to prevent the production of pro-inflammatory molecules such as interleukin, cyclooxygenase, tumour necrosis factor, and prostaglandin. Together with extracts from sorghum that is high in quercetin, flavone apigenin and flavanol quercetin have strong synergistic anti-inflammatory properties that increase their bioavailability in cells.

5. Conclusion

The study focused on nutritional and functional properties of sorghum sweet wort revelaed this beverage possessed a high nutritional value through an important weight gain of mouses. Also, sorghum sweet wort consumption have not negative effect on weight organ and blood parameters of mice. Eventual health benefits linked to sorghum sweet wort consumption was probably due to phenolic compounds. Before a defintive conclusion, additional research is required, including humans.

Abbreviations

SSK	Sorghum Sweet from Koumassi
SSY	Sorghum Sweet from Yopougon
DPPH	2,2-diphenyl 1-Picrylhydrazyl
AA	Antioxidant Activity

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Data Availability Statement

Data will be made available on request.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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