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Physicochemical and Microbiological Qualities of Traditional Cereal-Based Porridges Sold in Ouagadougou (Burkina Faso)

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Abstract Cereals are major sources of energy and micronutrients for people in West Africa, especially in Burkina Faso because they are included in many dishes like traditional porridge. The purpose of this study is to analyze the physicochemical and microbiological parameters of various traditional cereal-based porridges. The physicochemical analysis focused on pH, viscosity, acidity measurements, dosing energetic nutrients and evaluate energy densities of porridges. Aerobic total mesophilic flora (ATMF), coliforms, yeasts and molds and *Staphylococci* have been counted. Physicochemical analysis of the porridges were: pH (4 to 9.55), viscosities (32 to 187.5mm/sec), acidities (0.04 to 0.23g/100g), dry matter (5.04 to 49.97%), Ashes (0.64 to 05.00%), fats (06.60 to 18.26%), proteins (07.22 to 10.22%), carbohydrates (30.61 to 80.52%), energy densities (17.82 to 114.73 Kcal/100g). Microbiological analysis of porridges showed high loads of $1.19x10^4$ CFU/g, $5.5x10^2$ CFU/g, $1.56x10^3$ CFU/g and $6x10^1$ CFU/g for ATMF, coliforms, yeasts and molds and *Staphylococci*, respectively. Eleven ingredients were used for the production of porridges. This study shows that the actors of this sector need to be trained on good hygiene practices.

Keywords: *porridge, cereal, microorganism, nutrient, energy density*

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1. Introduction

Traditional cereal-based porridge is an alternative for young children to benefit from complementary feeding in developing countries [1,2]. In Burkina Faso, cereals used in the production of porridge are pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), maize (*Zea mays*) and rice (*Oryza sativa*) [3]. These cereals are subject to traditional processes which result in low fermented porridges in energy densities and nutrients [2,4,5]. Thus, the nutritional inadequacy of these porridges is linked to traditional processes that can negatively affect physicochemical parameters [6,7]. This can be a source of the various forms of malnutrition (protein-energy malnutrition and micronutrient deficiencies) especially in weaning children for whom this unbalanced diet is a form of aggression [8-11]. We can also notice the combined cereals-based porridge within the production industry. This combination contributes to the modification of the final product physicochemical and organoleptic parameters [12,13]. This factor explains the presence of various porridges on the market in Ouagadougou based on the modifications of *Bensaalga* and *Benkida* such as *Benkoonré*. Studies have shown the importance of fermentation processes through the microbiota by improving and preserving the quality of these porridges [14,15]. However, in the microbiota, we can distinguish some pathogenic microorganisms mostly deriving from unitary stages representing some potential threats to consumer's health [16]. It is then necessary to identify these microorganisms of nutritional importance and pathogens through the control of quality and fermentation. The goal of this study is to evaluate the quality of these porridges through the analysis of some physicochemical and microbiological parameters in all their diversity.

2. Materials and Methods

2.1. Sampling of Porridges

Samples were taken from 120 producers. Thus, these samples were reduced to a scale of 30 in proportion to each type of porridges so that the results representative. Tus, the porridges from all cereals were taken into account. Samples were taken under reals conditions sale "*in situ*". Some physicochemical parameters and microbiological analysis were carried out immediately after sampling in order to avoid modifications. The dry matter obtained for each sample was kept for the analysis of other physicochemical parameters such as proteins, lipids and sugars. Porridges were collected during October 2018.

2.2. Physicochemical Analysis

2.2.1. Temperature

Temperature was measured directly at the sampling site by pH-meter IP67-WATERPROOF coupled a thermometer. The value displayed on the screen was enregistred after to introduction of electrode into the porridge.

2.2.2. pH and Acidity

pH and acidity (Ac) were determined according to standard NF EN ISO 7305: 1973. About 5 g of porridges was introduced into a centrifuge tube supplemented with 30 ml of ethanol 95%. The whole is stirred for 1 h at 25°C with a rotary stirrer. The pH was determined by dipping the electrode of a pH meter in the sample and reading was done on the screen until a stable value was displayed. The sample is then centrifuged at 3500 rpm for 5minutes. In order to determine the acidity, 20 ml of the supernatant obtained after centrifugation was taken from a beaker and added with 6 drops of phenolphthalein. The titration was done with 0.05N NaOH while stirring until a persistent pink coloration was obtained for a few seconds. A blank is made with 20 ml of ethanol and six drops of phenolphthalein.

$$Ac\left(g\ lactic\ acid\ /100g\right)=\frac{0,0135\times V\ NaOH}{Pe}\times 100.$$

2.1.3. Viscosity

Consistency of the porridges was determined by using a branded Bostwick Consistometer CSC SCIENTIFIC 1-800-458-2558 which measures the flow velocity of the porridges at 45°C by measuring the distance travelled during 30 seconds (s) by the 100 ml of the porridge [16]. The values are expressed in mm/s.

2.1.4. Moisture Content and Dry Matter

Water and dry matter (DM) content were determined according to French standard NF V 03-707: 2000. In a crucible of known weight (P0) a quantity of the porridge was introduced to obtain a final weight (P1). The whole is placed in an oven at 105°C for 24 to 48 h. After drying, the sample is removed and weighed progressively in order to obtain the constant weight (P2). The content is deduced from that of the dry matter.

$$DM\left(\%\right)=\frac{P2-P0}{P1-P0}\times 100.$$

2.1.5. Total Ash Content

Ashes are determined according to the French standard V03-760: 1981. In crucibles of known empty weight (Pv), 3g of sample of the dried porridge were introduced. The crucibles containing the samples are placed in the oven at 550°C overnight, cooled in a desiccator for 1 h and then weighed again until a constant weight (Pf) is obtained.

$$Ash\left(\%\right)=\frac{Pf-Pv}{Pe}\times 100.$$

2.2.6. Protein Content

The protein contents of the samples were determined by the method of Kjeldahl according to the French standard V03-050 1970. The principle is based on the fact that organic nitrogen from the sample to be analyzed is transformed into inorganic nitrogen in ammoniacal form ($(NH4)_2SO_4$) due to the oxidizing action of the concentrated sulfuric acid in the presence of a catalyst. After displacement with sodium hydroxide as a strong base, the ammonia is distilled and then titrated in the presence of a colored reagent of boric acid by acidimetry. The total protein content is calculated by multiplying the amount of nitrogen by a conversion factor (6.25), i.e. 16% of nitrogen in the proteins.

$$\%P\ \left(Prot\acute{e}in\right)=\frac{Ve-Vb}{Pe}\times N\times 0,014\times 6,25\times 100.$$

2.2.7. Lipid Content

Lipid contents of the samples were determined by the Soxhlet extraction method according to the international standard ISO 659: 1998 [10], with hexane as solvent. The lipid content is determined by weighing after evaporation of the hexane from the cartridges in an oven.

$$Lipid\left(\%\right)=\frac{P1-P2}{Pe}\times 100.$$

2.2.7. Total Sugar Content and Energy Density

Total carbohydrate contents were determined by the differential method according to Egan et al. [17].

$$Carbohydrate\ content\ \left(\%\right)=100-\begin{bmatrix}Moisture\ \left(\%\right)+Protein\ \left(\%\right)\\+Lipid\ \left(\%\right)+Ashes\ \left(\%\right)\end{bmatrix}.$$

Energy densities of porridges were calculated from the coefficients of Atwater and Benedict [18].

$$Energy\ density\ \left(Kcal\ /100g\right)=\begin{bmatrix}4*Sugar\left(\%\right)+4*Protein\ \left(\%\right)\\+9*Lipid\ \left(\%\right)\end{bmatrix}*DM\left(\%\right).$$

2.3. Microbiological Analysis

2.3.1. Enumeration of Aerobic Total Mesophilic Flora

Aerobic total mesophilic flora (ATMF) was counted on the Plate Count Agar according to ISO 4833: 2003. The dishes were incubated in an oven at 37°C for 24 to 48 h.

2.3.2. Enumeration of Total Coliforms

Total coliforms were enumered according to ISO 4832 (2006). Seeding was done on violet red bile lactose agar (VRBL) and plates were incubated at 37°C during 24 h.

2.3.3. Enumeration of *Staphylococci*

Staphylococci were counted on the Chapman stone Agar according to ISO 6888-1 standard. After seeding, the dishes were incubated at 37°C for 48 h.

2.3.4. Enumeration of Yeasts and Molds

Yeasts and molds were enumered according to ISO 7954 (1988) after incubation the dishes at 30°C for 3 to 5 days onto SABOURAUD CAF Agar.

2.3.5. Enumeration of *Salmonella*

Salmonella were counted according to the AFNOR standard NF in ISO 6579 (2002) modified at two stages.

First stage: Pre-enrichment. It was done by incubating 25 ml of porridge sample added to 225 ml of sterilized Buffered Peptone Water at 37°C for 24 h for revivification of the stressed bacteria.

Second stage: Seeding of inoculum obtained from stage on *Salmonella-Shigella* agar (SS agar) for 72 h at 37°C.

2.3.6. General Expression of Microbiological Results

$$N = \frac{\sum c}{Vi \times 1{,}1 \times d}$$

N: number of microorganisms per g of porridge;
ΣC: sum of colonies counted on the two boxes of the dilution considered;
Vi: volume of inoculum in ml;
d: dilution considered.

2.4. Data Processing

The descriptive statistics (frequencies, averages) were performed by the Microsoft Office 2013 Excel spreadsheet. The R software was used for principal component analysis (PCA). The paint.net v 4.0.6 software was used for image processing.

3. Results

3.1. Physicochemical Parameters

3.1.1. Average of Physicochemical Parameters of Cereal-Based Porridges

The viscosities of the porridges vary from one cereal to another, between 187.50±0.06mm/s (BSM20) to 32.50±0.22mm/s (BKM14). For the same cereal, porridges with different values in flow velocities are also obtained. It is with pearl millet especially that extreme values in terms of flow velocities are observed. Temperatures are in the range of 33 to 71°C. The pH range between 4 and 5.99 in general except in the case of BKOM21 where the value (9.55±0.03) is almost twice the other porridges. Also, there is an increasing ash content (05.00±0.05) in BKOM21 compared to all other porridges and above the standards (2.9%). BSM20 represents the porridge with the highest acid content (0.23±0.01g/100g) but it remains very low for BKOM21 (0.04±0.01g/100g). As for dry matter, the highest content (49.97±0.03%) is found with BKSR4, a granular porridges (*Benkida*) based on red sorghum. The fine porridge (*Bensaalga*) of pearl millet (BSM20) has the lowest content (5.04±0.40%). The lowest ash content (0.64±0.00%) is observed in the rice porridge (BCR29). The values of parameters such as viscosity, pH, temperature, acidity, dry matter and ash content of the cereal-based porridges are shown in Table 1.

Table 1. Physicochemical parameters of cereal-based porridges

Sample	Viscosities (mm/s)	pH	T (°C)	Ac (%)	DM (%)	Ashes (%)
BKM1	58±1.40	5.80±0.03	71	0.15±0.01	7.27±0.50	1.31±0.05
BKM2	122.5±2.22	5.67±0.05	60	0.17±0.01	5.93±0.19	1.77±0.02
BSM3	106±0.55	5.69±0.04	60	0.13±0.01	6.71±0.60	1.22±0.01
BSM9	60±1.01	5.47±0.04	46	0.15±0.00	24.20±2.10	1.57±0.02
BSM10	108±1.12	5.30±0.03	48	0.23±0.02	14.56±6.43	1.31±0.02
BKM14	32.5±0.22	4.99±0.01	40	0.14±0.00	14.20±0.13	1.19±0.02
BSM15	105±0.33	5.71±0.01	40	0.15±0.00	7.40±5.28	1.32±0.48
BSM19	82.5±1.44	5.09±0.00	44	0.13±0.00	5.57±0.51	1.13±0.01
BSM20	187.5±0.06	4.84±0.00	45	0.20±0.01	5.04±0.40	1.34±0.01
BKOM21	53.5±0.38	9.55±0.03	45	0.04±0.01	7.30±1.41	5±0.05
BKM22	124.5±1.88	5.29±0.00	48	0.12±0.01	6.14±1.04	1.21±0.01
BKM24	102.5±0.57	4.85±0.00	44	0.19±0.01	5.11±0.35	1.51±0.00
BKM25	167.5±0.42	4.94±0.00	50	0.15±0.00	5.68±0.63	1.44±0.01
BKM26	132.5±0.06	4.83±0.01	50	0.18±0.00	5.25±1.23	1.54±0.00
BKM28	87.5±0.13	5.99±0.00	45	0.14±0.01	5.36±1.02	1.11±0.01
BKSR4	67.5±3.2	5.53±0.03	59	0.15±0.03	49.97±0.53	2±0.21
BSSR5	142±2.11	5.59±0.00	51	0.16±0.10	5.72±0.24	1.34±0.02
BKSB18	82.5±2.11	5.09±0.02	44	0.13±0.01	5.57±0.18	1.13±0.09
BKMA16	87.5±0.32	5.52±0.01	35	0.16±0.00	5.96±0.33	0.99±0.02
BKMA17	150±0.41	6.13±0.03	33	0.12±0.00	5.98±0.55	1.22±0.02
BKMA27	77.5±0.53	4.66±0.00	55	0.16±0.01	7.58±0.26	0.82±0.03
BCR11	42±2.03	5.13±0.01	44	0.11±0.02	10.60±0.14	0.71±0.01
BCR29	37.5±0.88	5.11±0.00	57	0.11±0.02	10.24±0.89	0.64±0.00

Legend: BKM: *Benkida* of pearl millet; BKS: *Bensaalga* of pearl millet; BKOM: *Benkoonré* of pearl millet; BKSR: *Benkida* of red sorghum; BSSB: *Bensaalga* of white sorghum; BKSB: *Benkida* of white sorghum; BKMA: *Benkida* of Maize; BCR: Porrige of rice coconut, DM: Dry matter, Ac: Acidity, T: Temperature.

Table 2. Physicochemical parameters of mixed cereals porridges

Codes	Viscosities (mm/s)	pH	T (°C)	Ac (g/100g)	DM (%)	Ashes (%)
BKMMA18	117.5±1.33	5.25±0.02	42	0.15±0.02	7.28±1.17	0.88±0.02
BKSRMA12	32.5±0.24	5.45±0.02	50	0.14±0.00	6.90±0.23	1.14±0.02
BKSRB13	32.5±0.77	4.99±0.00	40	0.14±0.01	14.20±0.63	1.19±0.00
BKMMA16	182.5±0.28	4.48±0.00	50	0.14±0.00	15.53±0.83	0.91±0.06
BKMMA17	74.5±0.49	5.01±0.03	56	0.14±0.01	5.95±0.66	1.32±0.20
BKMMA23	89±0.99	4.82±0.03	39	0.17±0.00	5.63±0.12	3.91±0/06
BKSRB30	155±0.18	5.37±0.00	45	0.12±0.03	04.34±0.57	0.56±0.78

Legend: BKMMA18: Pearl millet + Maize (*Benkida*), BKSRMA12: Red Sorghum + Maize (*Benkida*), BKSRB13: Red and White Sorghum (*Benkida*), BKMMA16: Pearl Millet + Maize (*Benkida*), BKMMA17: Pearl Millet + Maize (*Benkida*), BKMMA23: Pearl Millet + Maize (*Benkida*), BKSRB30: Red and White Sorghum (*Benkida*), DM: Dry matter, Ac: Acidity, T: Temperature.

3.1.2. Average of Physicochemical Parameters of Mixed Cereal-based Porridges

Table 2 reports the physicochemical parameters of mixed cereals porridges. The porridges from cereal combinations are all granular (*Benkida*) with viscosities between 32.50±0.24mm/s obtain for BKSRMA12 and BKSRB13; 182.50±0.28mm/s obtain for BKMMA16 as extreme values. The pH values are almost similar to those of a single cereal mixture, that is, between 4 and 5.48 corresponding to temperatures of 50°C or lower. The majority of the acidity contents are concentrated between 0.14g/100g and 0.15±0.02g/100g except for BKMMA23 (0.17±0.00g/100g) and BKSRB30 (0.12±0.03g/100g). Mixed-cereal porridges have the lowest dry matter values (04.34±0.57%), but there are also porridges with values up to 15.53±0.83% of BKMMA16 (Table 2).

3.1.3. Nutrients and Energy Densities of Traditional Porridges

3.1.3.1. Cereal-Based Porridges

Rice porridges are higher in fat content (Table 3) with a maximum content of 18.26±0.23% (BCR11) compared to low (06.60±0.00%) for BSM19 and BKSB18, which are produced from pearl millet and white sorghum. Protein levels range from 07.22±0.09% (BKSB18) to 9.93±0.19% (BKSR4). Carbohydrate contents (Table 3) have extremes ranging from 30.61±0.27% (BKRS4) to 79.46±0.62% (BKSB18). Energy densities range from 22.62±1.10 Kcal/100g of porridge (BKSB18) to 114.73±0.44 Kcal/100g (BKSR4) are recorded (Table 3).

3.1.3.2. Mixed Cereal-based Porridges

The combined cereals do not provide such significant changes in the minimum fat content that remains substantially equal to that given by single cereals (06.07±0.05%). But the highest value (07.64±0.04%) is significantly lower than given by the cereal-based porridge (18.26±0.23%). Protein levels, on the other hand, are slightly changing and range between 07.92±0.09% to 10.22±0.13%. The highest carbohydrate content is 80.52±0.14% (BKSRB30) versus 66.87±0.11 % (BKSRB13) as low. The energy densities did not change significantly and ranged from 17.82±0.15 Kcal/100g of porridge (BKSRB30) to 56.67±0.30 Kcal/100g (BKMMA16) compared to measure in cereal-based porridges (Table 4).

Table 3. Nutrients and energy densities of cereal-based porridges

Sample	Fats (%)	Proteins (%)	Carb (%)	ED (Kcal/100g)
BKM1	7.82±0.21	9.52±0.11	74.06±0.13	29.42±0.23
BKM2	7.46±0.01	9.01±0.08	75.81±0.09	24.12±0.17
BSM3	8.34±0.09	7.58±0.03	76.13±0.15	27.51±0.24
BSM9	8.34±0.10	7.73±0.16	58.15±0.85	81.25±1.20
BSM10	8.08±0.18	NA	NA	NA
BKM14	6.87±0.11	NA	NA	NA
BSM15	7.39±0.18	NA	NA	NA
BSM19	6.60±0.00	NA	NA	NA
BSM20	6.71±0.09	NA	NA	NA
BKOM21	8.29±0.18	8.97±0.05	70.44±0.30	43.75±0.57
BKM22	7.81±0.41	NA	NA	NA
BKM24	6.96±0.45	NA	NA	NA
BKM25	6.92±0.07	NA	NA	NA
BKM26	7.51±0.14	NA	NA	NA
BKM28	7.17±0.27	NA	NA	NA
BKSR4	7.49±0.01	9.93±0.19	30.61±0.27	114.73±0.44
BSSR5	8.18±0.11	7.27±0.16	77.48±0.11	23.60±0.09
BKSB18	6.60±0.18	7.22±0.09	79.46±0.62	22.62±1.10
BKMA6	7.36±0.63	7.92±0.10	77.75±0.73	24.37±0.80
BKMA7	7.79±0.05	NA	NA	NA
BKMA27	7.34±0.04	NA	NA	NA
BCR11	18.26±0.23	9.34±0.39	61.07±0.61	47.45±0.89
BCR29	17.28±0.15	NA	NA	NA

Legend: BKM: *Benkida* of pearl millet; BKS: *Bensaalga* of pearl millet; BKOM: *Benkoonré* of pearl millet; BKSR: *Benkida* of red sorghum; BSSB: *Bensaalga* of white sorghum; BKSB: *Benkida* of white sorghum; BKMA: *Benkida* of Maize; BCR: Porrige of rice coconut; NA: Not analyzed, ED: Energy Density, Carb: Carbohydrates.

Table 4. Nutrients and energy densities of mixed cereals-based porridges

Sample	Fat (%)	Proteins (%)	Carb (%)	ED (Kcal/100g)
BKMMA8	7.58±0.07	10.22±0.13	74.02±0.06	29.57±0.19
BKRSMA12	7.64±0.04	7.92±0.09	76.39±0.12	28.01±0.16
BKSRB13	6.87±0.019	10.87±0.29	66.87±0.11	52.92±0.21
BKMMA16	7.10±0.03	9.02±0.05	67.43±0.17	56.67±0.30
BKMMA17	7.51±0.02	NA	NA	NA
BKMMA23	7.39±0.07	NA	NA	NA
BKSRB30	6.07±0.05	8.50±0.02	80.52±0.14	17.82±0.15

Legend: Pearl Millet + Maize: BKMMA8; Red Sorghum + Maize: BKRSMA12; Red and White Sorghum: BKSRB13; Pearl Millet + Maize: BKMMA16; Pearl Millet + Maize: BKMMA17; Pearl Millet + Maize: BKMMA23; Red and White Sorghum: BKSRB30; NA: Not analyzed, ED: Energy Density, Carb: Carbohydrates.

3.1.3. Correlation Analysis

Correlation between cereals used and physicochemical parameters: Principal component analysis of the data indicates that the most viscous porridges are those obtained by mixing cereals or those made from rice (Figure 1). On the other hand, red sorghum porridge is more fluid with a high dry matter content (Figure 1a and Figure 1b). The most acidic porridges are those produced from maize and white sorghum

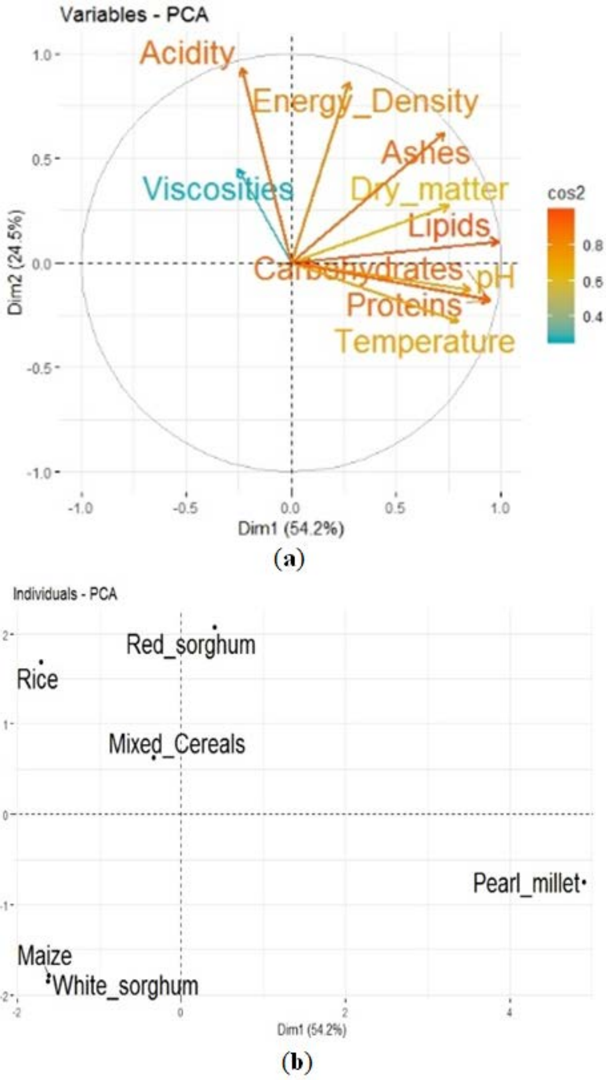

Figure 1. (a) Principal component analysis of parameters; (b) Principal component analysis of cereals

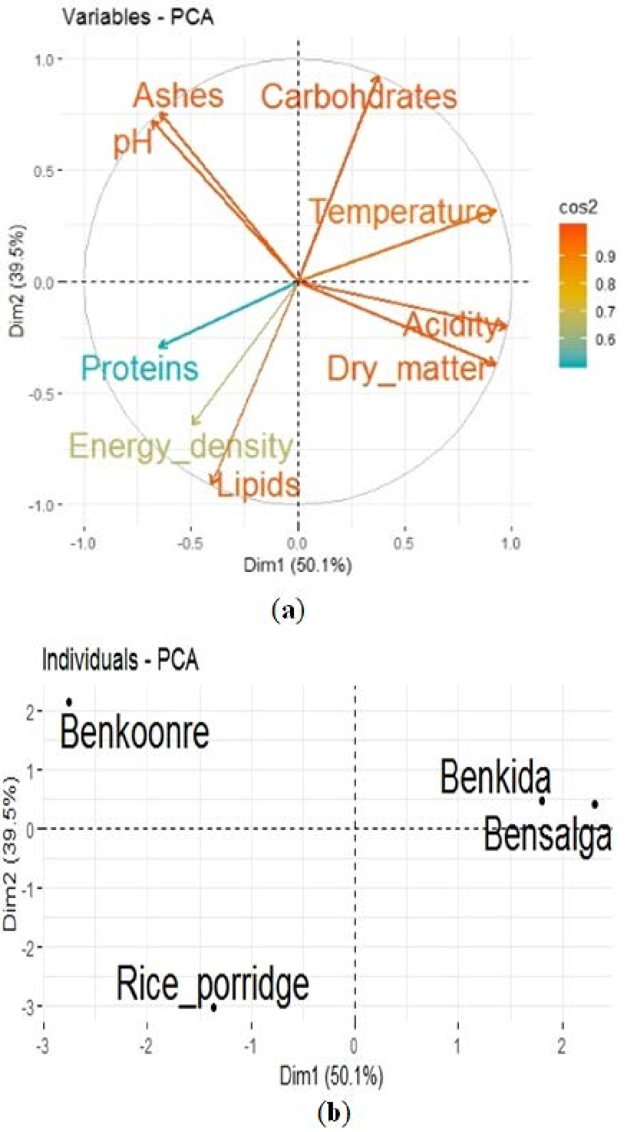

Figure 2. (a) Principal component analysis of the parameters; (b) Principal component analysis of porridges

Correlation between types of porridge and physicochemical parameters: Potash porridge (*Benkoonré*) has higher pH and ash values. The rice porridge is richer in fat, energy and protein. *Benkida* and *Bensaalga* have higher carbohydrate contents and viscosities compared to other types of porridge. These two porridges also contain more acid and dry matter compared to others (Figure 2a and Figure 2b).

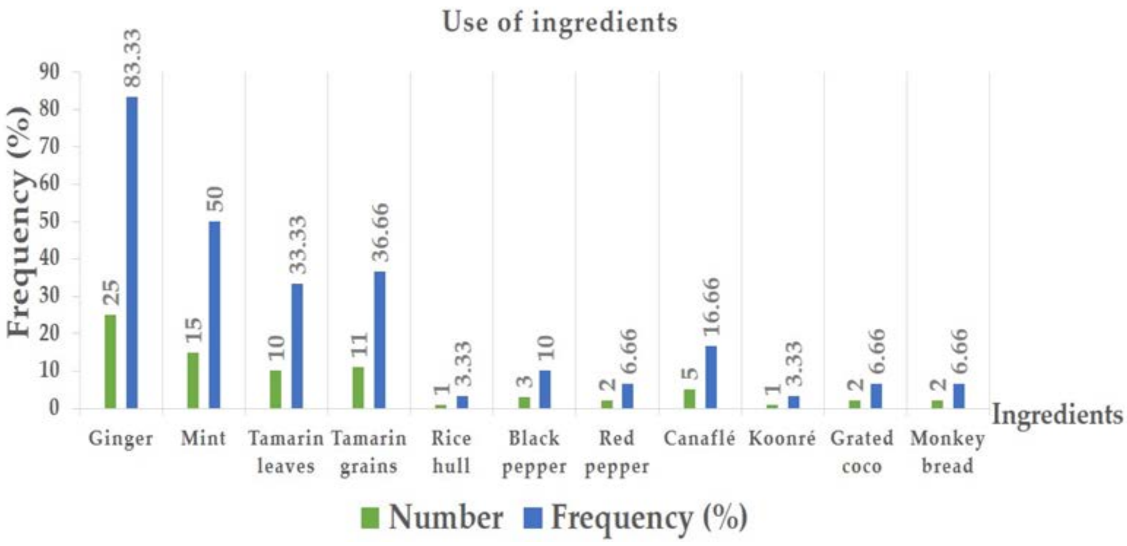

Figure 3. Frequency of the use of ingredients associated with porridges

Influence of ingredients on physicochemical parameters: Eleven ingredients were identified in the preparation of the porridge in Ouagadougou. The most used is Ginger (*Zingiber officinale* Rosc.) with a frequency of use of 83.33% against 03.33% frequency of use for the hull of rice and potash (*Koonré*). Mint, seeds and tamarind leaves are also used with respective frequencies of 50%, 36.33% and 33.33% (Figure 3).

Table 5. Microbiological quality of traditional porridges

Sample	ATMF	Coliforms	Y and M	*Staphylococci*	*SAL*
BKM1	$3.5×10^2$	$2×10^1$	$2×10^1$	$0.2×10^1$	Absence
BKM2	$2×10^1$	<10	<10	<10	Absence
BSM3	$1.19×10^4$	$5.5×10^2$	$1.56×10^3$	$6×10^1$	Absence
BSM9	$1.2×10^2$	<10	<10	<10	Absence
BSM10	$6×10^1$	$1.7×10^1$	$3×10^1$	<10	Absence
BKM14	$1.1×10^2$	$1×10^1$	$4×10^1$	$0.5×10^1$	Absence
BSM15	$4. ×10^2$	$0.7×10^1$	$1.8×10^2$	<10	Absence
BSM19	$4×10^3$	$1.02×10^2$	$1.45×10^3$	<10	Absence
BSM20	$3.06×.10^2$	$5.5×10^1$	$1.23×10^2$	<10	Absence
BKOM21	$4.7 ×10^2$	$2×10^1$	$1.30×10^2$	$2×10^1$	Absence
BKM22	$1.40 ×10^3$	$1.7×10^2$	$8.9×10^2$	$2×10^1$	Absence
BKM24	$8.09 ×10^2$	$1×10^1$	$2×10^2$	<10	Absence
BKM25	$5.1×10^2$	$6 ×10^1$	$1.43×10^2$	$3×10^1$	Absence
BKM26	$3×10^1$	$0.5 ×10^1$	$1×10^1$	<10	Absence
BKM28	$1.1 ×10^3$	$2×10^1$	$4.12 ×10^2$	$1×10^1$	Absence
BKSR4	$5.4 ×10^2$	$1.2×10^1$	$3.6×10^2$	<10	Absence
BSSR5	$5.02 ×10^2$	$5×10^1$	$1.13×10^2$	<10	Absence
BKSB18	$5.6×10^2$	$2 ×10^1$	$2.06×10^2$	$1×10^1$	Absence
BKMA6	$3.4 ×10^3$	$2.2 ×10^1$	<10	<10	Absence
BKMA7	$6.1.×10^2$	$6×10^1$	$3.2×10^2$	$2.1×10^1$	Absence
BKMA27	$4.4×10^2$	<10	<10	<10	Absence
BCR11	$2.8 ×10^2$	<10	<10	$0.5×10^1$	Absence
BCR29	$6.97 ×10^2$	<10	$1×10^1$	<10	Absence
BKMMA8	$9.6×10^2$	$1 ×10^1$	$8×10^2$	<10	Absence
BKSRMA12	$2×10^1$	$0.2 ×10^1$	$1×10^1$	<10	Absence
BKSRB13	$5 ×10^1$	<10	$2. ×10^1$	<10	Absence
BKMMA16	$1 ×10^2$	<10	$1×10^1$	<10	Absence
BKMMA17	$1.12×10^3$	$6×10^1$	$2.9×10^2$	<10	Absence
BKMMA23	$3×10^2$	$2 ×10^1$	$2×10^1$	$1×10^1$	Absence
BKSRB30	$1.25 ×10^3$	$1.8 ×10^1$	$3.7 ×10^2$	<10	Absence
Averages CFU/g	$1.05±2.23×10^3$	$0.5±1.06×10^2$	$2.64±4.03×10^2$	$0.64±1.29×10^1$	-
Satisfactory	$<10^5$	<20	$<10^3$	<10	Absence in 25g
Acceptable	$10^5≤N≤10^6$	$20≤N≤10^2$	$10^3≤N≤10^4$	$10≤N≤10^2$	
Unsatisfactory	$>10^6$	$>10^2$	$>10^4$	$>10^2$	

Legend: ATMF: Aerobic total mesophilic flora, Y and M: yeasts and molds and *SAL: Salmonella.*

3.2. Parameters Microbiological Quality of Porridges

3.2.1. Microbiological Quality of Cereal and Mixed Cereals-based Porridges

The total mesophilic aerobic flora (ATMF) varies from one sample to another between 2.10^{1} CFU/g to 1.19×10^{4} CFU/g with an average of $1.05\pm2.23\times10^{3}$ CFU/g (Table 5). Minumun loads in microorganisms such as yeasts and molds, coliforms and *Staphylococci* was less than 10 CFU/g in the porridges. Average loads of yeasts and molds, coliforms and *Staphylococci* in the porridges were $2.64\pm4.03\times10^{2}$ CFU/g, $0.5\pm1.06\times10^{2}$ CFU/g and $0.64\pm1.29\times10^{1}$ CFU/g, respectively. Maximum loads of yeasts and molds, coliforms and *Staphylococci* in the porridges were $1.56\text{x}10^{3}$ CFU/g, $5.5\text{x}10^{2}$ CFU/g and $6\text{x}10^{1}$ CFU/g, respectively. No *Salmonella* was counted in the samples taken (Table 5).

3.2.2. Assessment of Contamination

Aerobic total mesophilic flora was counted in all the porridges sampled with 100% meeting the satisfaction standard. The presence of coliforms is considered satisfactory at 53.33%, acceptable at 36.66% and unsatisfactory at 10%. For yeasts and molds, the satisfaction rate is 93.33% against 6.66% acceptability. No samples were considered unsatisfactory. Staphylococcal contamination was considered satisfactory at 83.33% against 16.66% acceptable frequency. No samples showed CFU/g greater than the acceptable margin for *Staphylococci*. For *Salmonella*, there is 100% satisfaction (Figure 4a). The overall appraisal score gives 53% satisfaction for all germs, 37% acceptability and 10% dissatisfaction (Figure 4b).

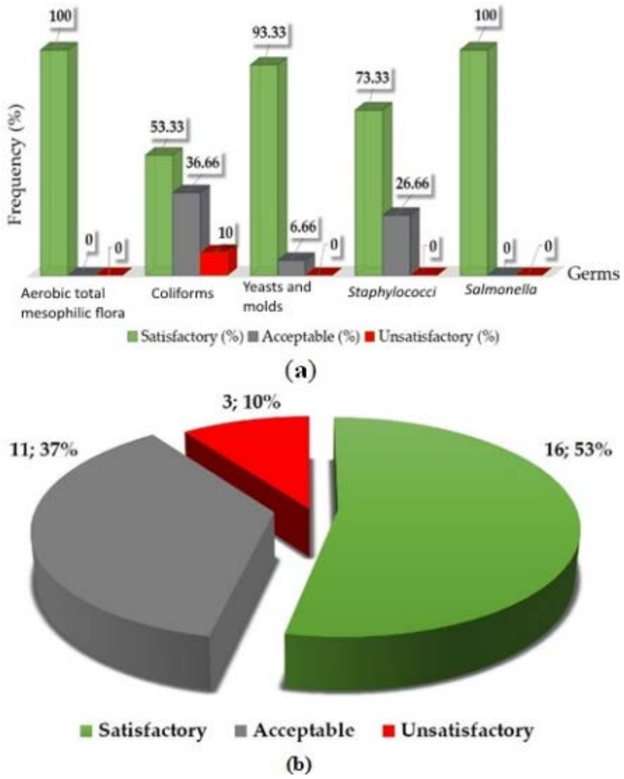

Figure 4. (a) Assessment of contamination by type of germs; (b) Overall assessment of samples

The rice porridge gives 100% of satisfactory followed by that of *Benkida* (6%). The most contaminated porridges are those of *Bensaalga*-type with a dissatisfaction rate of 28.57%. For cereals, it is rice that makes it possible to obtain porridge with more satisfaction (100%), followed by mixed cereals (74.42%), red sorghum (50%) and maize (33.33%). The porridges prepared with white sorghum have not been microbiologically satisfactory, but the acceptable margin remains high (100%) (Figure 5).

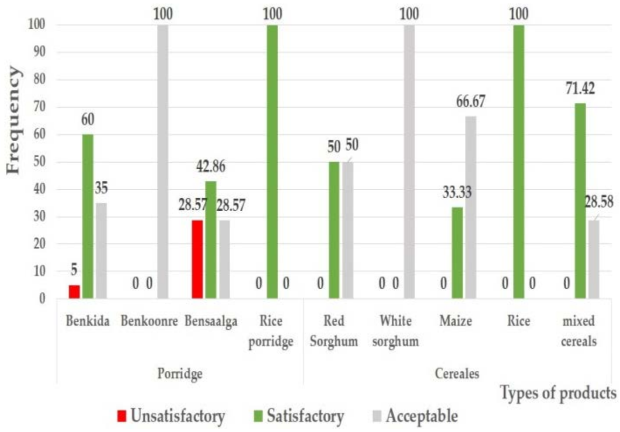

Figure 5. Assessment according to types of porridge and cereals

4. Discussion

Single-grain porridges have flow rates either below, or above the standards required by the Codex Alimentarius (120 mm/30sec) to serve as a complementary food [16,19,20]. According to some producers, the traditional processes can't provide porridges with gelled starch which can improve their fluidity to improve energy density [4,12,15]. In addition, an increase in dry matter leads to the thickening of the porridge. Consequently it can reduce the flow rate [21,22].

The pH of porridges are acidic but higher than the values (less than 4) found by other authors. The pH of porridges is an important indicator of their level of acidification to ensure their preservation [23,24]. The duration of soaking and settling are steps that, when not long enough, do not allow sufficient fermentation and this at the same time affects the acidity which remains low [25]. The only high value found at BKOM21 is related to the addition of potash (*Koonré*) which neutralizes the acidity and increases the ash content compared to other porridges.

The variations in temperature are due to sales periods and storage material for the porridge. The porridges sold in the mornings (6 am to 9 am) are naturally more influenced, because the ambient temperature is relatively low compared to that observed between 15 and 19 pm in the evening depending on the customer. The dry matter depends on the amount of material and quantity of water used for the preparation at the start of cooking. The energy nutrient content of cereal-based porridges can be modified by the various traditional treatments that can lead to considerable losses [10,12]. The addition of certain ingredients can also contribute to raising these levels [26], especially those of lipids (fats) and proteins. The high level of protein found in BKSRB13 is related to the mixture of the two sorghums that have higher protein fractions than millet and maize [27]. Protein levels of all the porridges collected are lower than those required for infant flours (15% protein per 100g DM porridge's). Also, the high lipid levels recorded in porridge made of rice due to the presence of grated coconut, which is very rich in lipids estimated between 12.74 and 54.84% [28]. For other porridges, the levels are lower than the standards required by the joint FAO / WHO commission in 2006 [29] which estimated the value at 8% of material in standard flours. These variations are also due to the diversity in cereals, which originally do not have the same nutrient content. These differences in nutritional composition are observed within the same species given the varietal differences caused by environmental conditions [30,31]. The levels of energy nutrients strongly influence the energy densities of porridges, justifying the variability in observed values. Tou et al. [32] estimated energy densities of traditional porridges at 30 Kcal/100g, with very low levels of energy nutrients and dry matter content. The materials are very low compared to the WHO recommendations that suggest an average of 30% for local porridge meant for supplemental feeding for children at weaning [12]. These energy densities have similarities with those obtained from infantile flours from semi-modern production units [33], but the lipid and protein contents remain low compared to standards.

The frequent use of ginger is linked to its availability all over the world, but also because of its various medicinal virtues [34]. Despite the fact that its culture is not widespread in Burkina Faso, it remains an accessible ingredient used by households because of the presence of some components (gingeroles, gingerdioles and gingerdiones) considered as powerful antioxidants [34]. Ginger extracts associated with porridge can therefore help avoid or treat stomach problems, indigestion, diarrhea, nausea and that is well known to producers [34]. However, due to the presence spices in it, its use is well controlled especially when it comes fora porridge meant for children.

Some ingredients like mint, tamarind seeds and leaves (*Tamarindus indica*) are known for their ability to preserve food [35]. Indeed, mint (*Mentha spicata*) is known for its strong flavor because of essential oils, flavonoids, phenolic acids and menthol [35]. This ingredient provides potassium and folic acid (vitamin B9). The tamarind has an acidifying feature and it is therefore more used for this property than for the flavoring taste [35]. Nomel et al [36] reported that potash was mostly used as an ingredient to improve the fluidity, digestibility and preservation of the tô (a more solid form of cereal based-food). This property can be attributed to *Koonré* when added to the porridge explain more its use by some producers. The use of grated coconut matches with women concern to offer a porridge with new, acceptable and economically profitable features. This is the reason why porridge made of coconut is three times more expensive than the other ones. The high viscosities indicate the lack of control by the producers to establish a balance between the amount of water on one hand and the proportions of cereals during mixing on the other hand. It should also be noted that in the case of rice, the soaking time is reduced and the grains remain visible in the porridge, which slows the flow.

The presence of ATMF originates from the raw material itself [27]. These microorganisms decrease in number after the cooking operation, which partly explains the number of CFU/g below the satisfaction standard (10^5 CFU/g) for the ATMF. A study confirmed the reduction of the ATMF by the effect of acidity and temperature in traditional pearl millet porridge. The acidification of porridges inhibits the growth of a large number of microorganisms through which potential pathogens, thus reducing their number. When the cooking operation is carried out under optimum conditions, this considerably reduces the ATMF. The number of coliforms is mainly located in the satisfaction margin. A fraction of the samples is considered unsatisfactory, which is an indicator of fecal or oral contamination and some of the germs may represent a danger to the consumer. As for porridges, the risk of contamination beyond acceptable standards is a sign of hygiene rules breach (hand hygiene, premises, equipment, etc [27,37]. There is a need to sensitize the actors on the precautions they have to take in order to preserve the porridges out of contaminations. The fungal flora (yeasts and molds) counted in some samples are not in compliance with the satisfaction standard, but remain acceptable ($<10^3$ CFU/g). Molds are particularly at the origin of the deterioration of the taste of porridge if their presence is not regulatory [38]. *Staphylococci* counted in some samples are above the satisfaction limit, which may be at risk. Contamination by *Staphylococci* may be of exogenous origin, that is to say by contact with the working equipment, or simply related to manipulations made at some of the production process.

Rice provides more satisfaction both in the type of porridge and cereal. This is because its use does not require complex steps compared to other cereals such as maize and white sorghum. In fact, these last two cereals require shelling before being used because of their indigestible envelope and full of antinutritional factors. The complexity of operations is a potential risk of contamination especially when it is done manually.

Efforts are being made by the government, the University Joseph KI-ZERBO and research centers (DTA) to improve the quality of traditional foods, but expectations are still enormous for providing baby food for young children.

5. Conclusion

Traditional porridge contributes to improving the nutrition of people, especially those of young children as for supplementary foods during weaning. In Ouagadougou, as in most urban centers, there is a diversity of production processes, but also in the use of cereals. This justifies the diversity of porridges sold in the streets. They have energy densities below the standards proposed by the Codex Alimentarius and some authors as well. Pathways for improving the levels of energy nutrients and the balance of other physicochemical parameters are necessary. Also, educating producers about best hygiene practices can ensure healthy and nutritionally balanced porridges to the profit of consumers.

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References

[1] Désiré, K.N., Adjéhi, D., Antoine, Y.B., Mireille, A.B.W.A., Nazaire, K., Etienne, D and Marcellin, D.K. Effect of thermals constraints on enteropathogenic *Escherichia coli* survival in porridges based on maize (*Zea mays*) or millet (*Pennicetum glaucum*) flour traditionally made in Côte d'Ivoire, *International Journal of Agricultural Policy and Research,* 4. 217-226. 2016.

[2] Tsopzong, A.B.T., Tene, S.T, Boungo, G.T., Zokou, R and Klang, J.M. Effect of germination time on the diastasic power of maize (Coca-sr variety) and paddy rice (Nerica L.56 variety): Application of amylase rich flours and their extracts in the fluidification and improvement of the energy density of fermented maize gruel, *Journal of Herbal Medicine Research,* 3. 1-16. 2018.

[3] Songre-Ouattara, L.T., Bationo, F., Parkouda, C., Dao, A., Bassolet, I.H.N and Diawara, B. Qualité des grains et aptitude à la transformation: cas des variétés de *Sorghum bicolor*, *Pennisetumg laucum* et *Zea mays* en usage en Afrique de l'Ouest, *International Journal of Biological and Chemical Sciences,* 9. 2819-2832. 2015.

[4] Mouquet-Rivier, C., Traoré, T., Soma, A., Kaboré, C., Trèche, S. Both encouraging feeding style and high energy density may increase energy intakes from fermented millet gruels eaten by infants and toddlers in Ouagadougou. *Appetite,* 99. 245-253. 2016.

[5] Sabo, H., Illia, M.N.A., Rabiou M.M., Maazou, A.B., Douma, S., Chaibou, I., Amakou, I and Idrissa, H. Recettes Alimentaires A Base Des Graines De *Boscia Senegalensis* Au Niger: Cas Des Communes De Bambeye Et Banibangou. *European Scientific Journal,* 14. 195-206. 2018.

[6] Bationo, F. *Les aliments céréaliers fermentés africains: un autre moyen de participer à la couverture des besoins en folates*. Thèse de doctorat, Université de Montpellier, 289. 2018. Available: https://tel.archives-ouvertes.fr/tel-02045892/document.

[7] Kayodé, A.P.P., Abogou, F.U.G., Hounkpatin, W.A and Hounhouigan, D.J. Effets des procédés de transformation sur la valeur nutritionnelle des formulations de bouillies de complément à base de sorgho, *International Journal of Biological and Chemical Sciences,* 6 (5). 2192-2201. 2012.

[8] Brnić, M., Hurell, R.F., Songré-Ouattara, L.T., Diawara, B., Kalmogo-Zan, A., Tapsoba, C and Wegmüller, R. Effect of phytase on zinc absorption from a millet-based porridge fed to young Burkinabe children, *European journal of clinical nutrition,* 71(1). 137-141. 2017.

[9] Sanou, S., Ayantunde, A and Nianogo, A.J. Consommation alimentaire des ménages et déterminants de la diversité alimentaire: cas de quatre communes dans la région du Nord, Burkina Faso, *International Journal of Biological and Chemical Sciences,* 12(4). 1784-1801. 2018.

[10] Songré-Ouattara, L.T., Gorga, K., Savadogo, A., Bationo, F and Diawara, B. Evaluation de l'aptitude nutritionnelle des aliments utilisés dans l'alimentation complémentaire du jeune enfant au Burkina Faso/Evaluation of the nutritional ability of foods used in the complementary feeding of young children in Burkina Faso, *Journal de la Société Ouest-Africaine de Chimie,* 41. 41-50. 2016.

[11] Zannou-Tchoko, V., Ahui-bitty, L., Kouamé, K., Kouamé, G and Dally, T. Utilisation de la farine de maïs germé source d'α-amylases pour augmenter la densité énergétique de bouillies de sevrage à base de manioc et son dérivé l'*attiéké, Journal of Applied Biosciences,* 37. 2477-2484. 2011.

[12] Amoin, A.K.K.A., Agbo, E.A., Dago, A.G., Gbogouri, A.G., Brou, D.K and Dago, G. Comparaison des caractéristiques nutritionnelles et rhéologiques des bouillies infantiles préparées par les techniques de germination et de fermentation, *International Journal of Biological and Chemical Sciences,* 9(2). 944-953. 2015.

[13] Tshite, F.N and Ndianabo, M.J. Mise au point d'une farine précuite à base de maïs (*Zea mays*) et de soja (*Glycine max*) par la méthode traditionnelle, *International Journal of Biological and Chemical Sciences,* 9 (6). 2608-2622. 2015.

[14] Fofana, I., Soro, D., Yeo, M.A and Koffi, E.K. Influence de la fermentation sur les caractéristiques physicochimiques et sensorielles de la farine composite à base de banane plantain et d'amande de cajou, *European Scientific Journal,* 13(30). 395-416. 2017.

[15] Saubade, F. Potentiel nutritionnel du microbiote d'aliments fermentés à base de céréales: le cas des folates. Thèse de doctorat, Université de Montpellier, 275. 2016.

[16] Elenga, M., Massamba, J., Kobawila, S., Makosso, V and Silou, T. Evaluation et amélioration de la qualité nutritionnelle des pâtes et des bouillies de maïs fermenté au Congo, *International Journal of Biological and Chemical Sciences,* 3(6). 1274-1285. 2009.

[17] Egan, H., Kirk, R and Sawyer, R. Pearson's Chemical Analyses of Food (8th edition) Churchill. Livingstone: London-UK, England, 591. 1981.

[18] Atwater, W.O. and Benedict, F.G. Experiments on themetabolism of matter and energy in the human body.US Department of Agriculture. (1899) Washington, D.C. Bulletin 69. 112. 1899.

[19] El Tou, H., Mouquer, C., Trèche, S., Guyot, J.P and Traoré, A.S. *Caractérisation des procédés traditionnels de fabrication des bouillies de petit mil fermenté dans 24 micro-ateliers de production à Ouagadougou.* Forum National de la Necherche Scientifique et des Innovations Technologiques *(FIRSIT),* Ouagadougou, 15-18 Mai, 2002.

[20] Fogny, N.F., Madode, E.Y., Laleye, F.F., Amoussou-Lokossou, Y and Kayodé, A. Formulation de farine de fonio enrichie en ressources alimentaires locales pour l'alimentation complémentaire des jeunes enfants au Bénin, *International Journal of Biological and Chemical Sciences,* 11(6). 2745-2755. 2017.

[21] Elenga, M., Tchimbakala, M.S and Sahou, A. Amélioration de la qualité nutritionnelle des bouillies d'igname et leur efficacité chez les rats de souche wistar, *Journal Applied Biosciences,* 103 (1). 9819-9828. 2016.

[22] Kayode, A.P.P., Ahouanse, I.S., Kotchoni, S.O and Hounhouigan J.D. Optimisation du procédé traditionnel de maltage du sorgho pour la production de boissons fermentées. *International Journal of Biological and Chemical Sciences,* 5(4). 1552-1561. 2011.

[23] Bokossa, I.Y., Banon, J.S., Tchekessi, C.C., Sachi, P., Djogbe, A and Bleoussi, R. Production de *Ablo*, un aliment céréalier fermenté du Bénin: Synthèse bibliographique [Production of *Ablo*, a food cereal fermented of Benin: Bibliographic synthesis], *International Journal of Innovation and Applied Studies,* 16(2). 356-369. 2016.

[24] Tchekessi, C.K.C., Yaou, I.B., Agbangla, C., Adeoti, K.., Dossou-Yovo, P and Assogba, E. Caractérisations physicochimiques et microbiologiques d'une pâte traditionnelle" *gowé*" fabriquée à base de maïs au Bénin. *Journal Recherche Science Universel.*15(2): 377-387, 2013.

[25] Messad, F., Létourneau-Montminy, M.P., Charbonneau, E., Sauvant, D and Guay, F. Prediction of standardized ileal digestibility and essential amino acid content of ingredients in swine: A meta-analysis, *Journées Recherche Porcine,*. 47:204-221, 2015.

[26] Sidibe, S., Coulibaly, A., Koné, D and Doumbia, M. Amélioration de la viscosité et de la densité énergétique des bouillies infantiles préparées à partir de farines composées à base de riz, de niébé, de soja et d'arachide, *Agronomie Africaine,* 29(1). 53-61. 2017.

[27] Tchekessi, C., Bokossa, A., Agbangla, C., Azokpota, P., Daube, G., Scippo, M.L and Bokossa, I.Y. Production and microbiological evaluation of three types of" *Dègué*", a local fermented drink made from milk in Benin. *International Journal of Multidisciplinary and Current Research,* 2. 714-720. 2014.

[28] Kodjo, N.F., Konan, K.J.L., Doue, G.G., Yao, S.M., Allou, K and Niamke, S. Caractérisation physicochimique des composantes de noix immature et mature de l'hybride de cocotier (*Cocos nucifera* L.) Nain Jaune Malaisie x Grand Vanuatu cultivé en Côte d'Ivoire, *Journal of Animal &Plant Sciences* 27(1). 4193-4206. 2015.

[29] Joint, F.A.O. and W.E.C.o.F. Additives. Safety evaluation of certain food additives. 2006. Available: https://apps.who.int/iris/bitstream/handle/10665/43265/9241660546_eng.pdf.

[30] Banon, J.S., Bokoss, IY., Tchekessi, C.C., Bleoussi, R., Sachi, P., Dogbe, A., Assogba, K., Bade, F., Dahouenon-Ahoussi, E., Azopkota, P and Mensah, G.A. Production of Millet-Based (*Pennisetum glaucum*) *Ablo* and Sorghum-Based (*Sorghum bicolor*) *Ablo* Cultivated in the Republic of Benin, *International Journal of Current Microbiology and Applied Sciences,* 6(3). 276-282. 2017.

[31] Boussari, Y.A.O., Chabi, N.W and Houssou, P. Fortification de farines infantiles par les feuilles de *Calotropis procera* et de *Fagara xanthoxyloïdes*. Mémoire de licence, Université d'Abomey-Calavi, Bénin, 59. 2016.

[32] Tou, E.H., Mouquet, C., Guyot, J.P., Traoré, A.S and Trèche, S. *Essai de modification du procédé traditionnel de fabrication des bouillies de mil fermenté ben-saalga en vue d'augmenter leur densité énergétique.* 2nd International Workshop, Ouagadougou, 23-28 Nov 2004.

[33] Sanou, A., Tapsoba, F., Zongo, C., Savadogo, A and Traoré, Y. Etude de la qualité nutritionnelle et microbiologique des farines infantiles de quatre unités de production: CMA saint Camille de Nanoro, CSPS Saint Louis de Temnaoré, CM saint Camille d'Ouagadougou et CHR de Koudougou. *Nature & Technology*, 17. 25-39. 2017.

[34] Nandkangre, H., Ouedraogo, M and Sawadogo, M. Caractérisation du système de production du gingembre (*Zingiber officinale* Rosc.) au Burkina Faso: Potentialités, contraintes et perspectives. *International Journal of Biological and Chemical Sciences,* 9(2). 861-873. 2015.

[35] Massieke, A.A.R.S., Tapsoba, F.W.B., Kaboré, D., Seogo, I., Tankoano, A., Dicko, M.H., Toguyeni, A and Sawadogo-Lingani, A. Etude sur la capacité de production, du circuit de commercialisation et de la consommation du *zoom-koom* vendu dans la ville de Ouagadougou au Burkina Faso. *International Journal of Biological and Chemical Sciences,* 11(5). 2294-2305. 2017.

[36] Nomel, C.A.M., Kouadio, Y., Dan, G.C., Komadé, T and Kouamé, P.L. Enquête sur les Farines Céréalières et les Ingrédients Utilisés Dans la Préparation de la Pâte Alimentaire Traditionnelle Appelée" *Tôh*" à Abidjan (Côte d'Ivoire), *European Scientific Journal,* 15(6). 508-524. 2019.

[37] Maiwore, J., Baane, M.P., Ngoune, L.T., Fadila, J.A., Yero, M.Y and Montet, D. Qualité microbiologique et physicochimique des laits fermentés consommés à Maroua (Cameroun). *International Journal of Biological and Chemical Sciences,* 12(3). 1234-1246. 2018.

[38] Kouadio-Yapo, C.G., Dou, G.S.P., Aka, N.A.D., Zika, K.D., Adoubryn, K.D and Dosso, M. Identification des espèces de levures isolées de l'*attiéké* commercialisé sur les marchés à Abidjan (Côte d'Ivoire): étude préliminaire, *Journal de Mycologie Medicale,* 28(2). 305-309. 2018.