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Proximate Composition and Microbiological Quality of Millet Gruels Sold in Abidjan (Cote d'Ivoire)

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Abstract **– The proximate composition and the microbiological quality of thirty millet gruel samples collected in five areas of Abidjan (Côte d'Ivoire) were analyzed. The Total Aerobic Mesophilic Flora (TAMF), Total coliform (TC) and Thermotolerant Coliforms (THC) were used to assess the microbiological quality according to standard methods. The pH, titratable acidity, dry matter, ash, protein, lipid, total carbohydrate, reducing sugar, energy value, iron, calcium and magnesium contents were used to assess the proximate composition according to standard methods. Results were compared to international recommended levels. We observed a significant variability among millet gruel samples for all the parameters studied (P = 0.05). Only 6.7% of samples were outside of the recommended limits for both TAMF and yeast counts. Moulds, TC and THC were not detected in all the samples. Gruel samples had acceptable average values of pH, titratable acidity, dry matter, ash and reducing sugar contents. Gruel samples were characterized by very low energy values, lipid, protein, total carbohydrate, iron, calcium and magnesium contents, well below recommended levels for complementary foods. Fortification of the millet gruels together with the use of starter culture during processing is recommended.**

Keywords **– Macro/Micronutrient, Microbiological Quality, Millet Gruel, Proximate Composition, Weaning Food.**

I. Introduction

In Côte d'Ivoire, traditional cereal gruel commonly called 'baca' and 'coco baca' are still prevailing in both rural and urban areas. Millet [Pennisetum glaucum (L) R, BR], maize (*Zea mays*), or rice (Orysa sativa) grains are used either singly or mixed to produce these gruels [1]. In Abidjan baca' and 'coco baca' are sold, early in the morning, by gruel sellers and/or producers just in front of her home or in area of great meetings such as markets, bus stations, schools, industrial areas, etc. The gruel is called 'baca' or 'coco baca', depending on whether cereal granules or a single cereal are added or is used, respectively, during cooking or not. 'Coco baca' is made from a mixture of millet and maize flours and it is smooth in texture. To produce 'baca', the millet, maize or rice flour is sieved, mixed with a quantity of water and rolled by hand to obtain a granulated product. The granulated product could be left at ambient temperature for few hours or not. Both cereal granulated product for 'baca' and millet/maize flour for 'coco baca, are added in boiling water and cooked to gelatinization. The product is a thin grayish gruel which is added with sugar before consumption [2].

Several fermented cereal-based gruels such as 'ogi', 'ben-saalga' or 'ben-kida', and 'koko' in West Africa [3]-[4]-[5], 'togwa' in Tanzania [6], and 'mahewu' in South Africa [7] have been documented. These traditional gruels are mainly consumed as breakfast by adults and as complementary food by young children. Apart from energy, the cereal gruel used as weaning food is usually inadequate in other nutrients, leading to widespread protein energy malnutrition and its complications, during the weaning period [8].

In Côte d'Ivoire, taking into account the recommendations for a complementary food [9] and the results on the nutritional status of children under to 2 years of [10], attempts to produce weaning food which are quite rich in protein and other nutrient have been made. Ref. [1] or [11] has performed, respectively, a combination of flours (millet, maize, rice) or cereals (*Zea mays*) with source of rich protein (*Cajanus cajan*) and starchy roots [*Colocasia Esculenta* (L) Schott] in the view to improve the nutritional quality of infantile flours. However, the effectiveness of these formulations to improve young Ivorian children and infants nutritional status was not yet clearly demonstrated. Although there have been extensive researches on fermented cereal gruels from several African countries, no report exists on the proximate composition and microbial quality of the reedy-to-eat cereal gruels sold in Côte d'Ivoire. The aim of this study is to analyze the proximate composition and microbial quality of millet gruels sold in Abidjan, with the aim of providing a rational basis for the improvement of 'baca'.

II. Material and Methods

A. Sampling

Thirty (30) samples of millet gruels sold (approximately 150 g in polyethylene bags) in the streets were collected from five areas of Abidjan, the economical capital of Côte d'Ivoire, namely Abobo, Adjamé, Cocody, Treichville and Port-Bouët. Six samples were collected in each area from gruel sellers, mainly in areas of great meeting such as bus stations and markets. Millet gruels were sampled as sold by gruel sellers, with added sugar, early in the morning (between 5 am and 8 am) in March 2013. Samples were kept on ice at 0°C and transported to the laboratory for analyses.

B. Proximate composition

Millet gruel samples were analyzed for their pH, titratable acidity value, and dry matter and ash contents [12]. Ten (10) ml of distilled water was homogenized with 10 g of sample, and the pH was measured with a combined glass electrode and pH meter. The titratable acidity was expressed as lactic acid equivalent (% w/w) and was obtained by titration with 0.1 N NaOH, using 1%

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phenolphthalein as the indicator. Acid equivalent was the amount of NaOH consumed in ml. Each ml of 1N NaOH is equivalent to 90.08 mg of lactic acid. The dry matter was measured after drying of samples at 105°C until constant weight was achieved. Ash content was determined by incineration of samples at 530°C in an aching muffle furnace. Proteins content ($N \times 6.25$) was determined by the Kjeldhal method [13]. Total lipid contents were determined according to the method of [14] as modified by [15]. Total carbohydrates were determined according to the method of [16] and modified by [17] using ethanol, oxalic acid and lead acetate. Reducing sugars were quantified by the oxidoreduction method using 3.5-dinitrosalysislic acid (DNS) as oxidizing agent [18]. The energy value of millet gruels was then evaluated according to [19]. After mineralization at 530°C, total iron, calcium and magnesium contents were assess using standard procedures [12].

C. Microbiological analyses

Ten g (10g) of millet gruel sample were serially diluted and spread-plated for determination of microorganism counts. The Total Aerobic Mesophilic Flora (TAMF) was determined by plating 1ml of the serially diluted sample on Nutrient agar and incubating at 30±1°C for 72h. The presumptive Total Coliform (TC) counts and Thermotolerant Coliforms (THC) were determined by plating 1 ml of the serially diluted sample on Violet Red Bile Agar (VRB) and incubating at 37±1°C for 24h. Confirmation was done by fermentation of lactose and indole at 44±1°C after 24h incubation. The fungus counts were determined by plating 1 ml of the serially diluted sample on Oxytetracycline Glucose agar (OGA) and incubating at 25±1°C for 72h.

D. Data analysis

One sample was collected from each gruel seller and experiments were performed in duplicate. Data on proximate composition of millet gruel are presented as means ± Standard Deviation (SD) (n = 2) and were compared to recommended nutrient intake (RNI) for children under 1 year of age [20]. For each sample, microbial counts were performed in duplicate and data are presented as means ± SD (n = 4). Data were compared using the Tukey's HSD test (Statistica 8.0, Stat Soft Inc., 2007). The level of significance was set at P = 0.05. Grouping of millet gruel samples based on proximate composition was performed by principal component analysis (PCA) (Statistica 8.0, Stat Soft Inc., 2007).

III. Results and Discussion

A. Proximate composition

Taking into account survey data, millet gruel was used in this study as it was the most cereal gruel consumed early in the morning in Abidjan (data not shown). Proximate composition of millet gruels sold in Abidjan compared to requirements for children under 1 year of age [20] are presented in Table 1. The pH or titratable acidity (% lactic acid equivalent) values of millet gruel samples sold in Abidjan ranged between 3.44 ± 0.02 or 0.07 ± 0.01g/100g gruel and 4.27 ± 0.04 or 0.46 ± 0.01g/100g gruel, with an average value of 3.95 ± 0.02 or 0.20 ± 0.02g/100g gruel (Fig. 1A, B), respectively. We observed a significant variation in pH or titratable acidity values among millet gruel samples (P = 0.05). It clearly appeared that millet gruel sold in Abidjan is an acidic cereal beverage. The acidic average pH value is compared with the average pH (3.88) of 'ben saalga' millet gruel sold in Ouagadougou (Burkina-Faso) which was between 3.75 and 4.00 [4]. Most of pH values of millet gruels sold in Abidjan were around 4.00 like others cereal-based fermented gruel of Africa that undergo lactic acid fermentation [21]. The average lactic acid content is comparable with that of the fermented maize dough 'mawé' (0.17 g/100g) bought in Benin [22]. Lactic acid fermentation possibly enhanced the characteristic sour taste of cereal-based gruel and has the advantage of preventing or limiting the growth of food-borne pathogens or undesirable microorganisms, even after cooking [23]-[24].

Table 1: Proximate composition of millet gruels sold in Abidjan compared to Ref. [20] requirements

	Millet mush samples [a] (this work)		[20]
Proximate paramter	Mean value	Range	RNI[b] for children under 1 year of age
Dry matter (%)	17.50 ± 0.28	13.33 ≤ x ≤ 23.84	-
pH	3.95 ± 0.02	3.44 ≤ x ≤ 4.27	-
Titratable acidity (%)	0.20 ± 0.02	0.07 ≤ x ≤ 0.46	-
Total ash (%)	0.95 ± 0.12	0.28 ≤ x ≤ 2.23	< 3
Proteins (g/100 g)	2.29 ± 0.06	0.02 ≤ x ≤ 18.64	13-14
Lipids (g/100 g)	4.02 ± 0.80	1.73 ≤ x ≤ 7.93	10-25
Carbohydrates (g/100 g)	7.84 ± 0.90	2.93 ≤ x ≤ 16.64	64
Reducing sugars (g/100 g)	0.24 ± 0.08	0.02 ≤ x ≤ 0.44	-
Energy value (Kcal/100g)	77.00 ± 5.34	35.18 ≤ x ≤ 157.15	650
Iron (mg/100g)	5.00 ± 0.87	1.37 ≤ x ≤ 12.77	21
Calcium (mg/100g)	24.31 ± 2.12	3.59 ≤ x ≤ 71.70	400
Magnesium (mg/100g)	39.81± 1.50	6.40 ≤ x ≤ 65.43	40

[a] Results for 60 samples
[b] RNI : Recommended nutrient intake

Dry matter content of millet gruel samples ranged between 13.33 ± 0.24 g/100g and 23.84 ± 0.99g/100g gruel with an average value of 17.50 ± 0.28 g/100g gruel (82.50 % moisture content average value) (Fig. 1C). We observed a significant variation in dry matter content values among millet gruel samples (P = 0.05). These results were different to data found in 'ben-saalga' from Burkina-Faso where dry matter level ranged between 5.53 and 8.09 g/100g gruel with an average value of 7.06 g/100g gruel [4]. Millet gruels sold in Abidjan had a higher concentration than that sold in Ouagadougou. These differences in dry matter content could be due to differences in processing conditions between gruel producers of Abidjan and Ouagadougou.

Ash content of millet gruel samples ranged between 0.28 ± 0.01 g/100g and 2.23 ± 0.01 g/100g gruel with an average value of 0.95 ± 0.12 g/100g gruel (Fig. 2A). We observed a significant variation in ash concentrations among millet gruel samples (P = 0.05). These results were different to data found in 'ben-saalga or ben-kida from Burkina-Faso where dry ash content ranged between 0.90 and 1.82 g/100g gruel with an average value of 1.42 g/100g gruel [4]. However, the ash content of millet gruels

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sold in Abidjan was in line with the recommended level which is of about less than 3 g/100 gruel for children under 1 year of age [20] (Table 1).

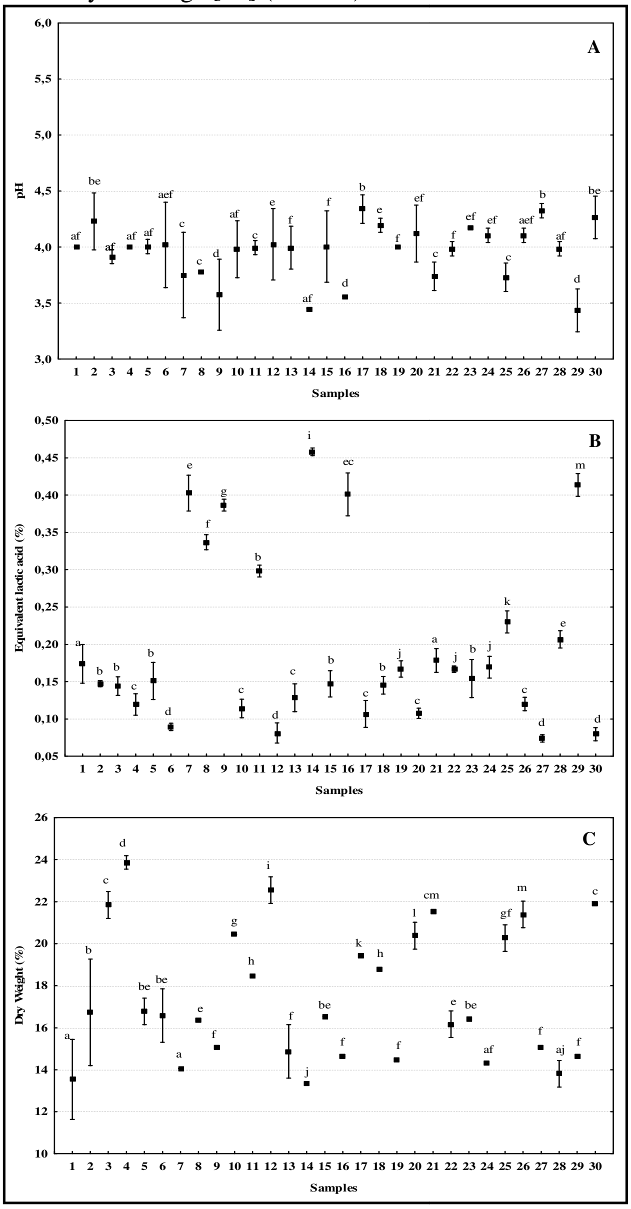

Fig.1. pH (A), titratable acidity (B), and dry matter content (C) of millet gruels sold in Abidjan. Values are presented as means ± Standard Deviation (SD) (n = 2). Means with different letters are significantly different (*P* = 0.05, Tukey HSD test)

Proteins content of millet gruel samples ranged between 0.02 ± 0.001 g/100g and 18.64 ± 0.09 g/100g gruel with an average value of 2.29 ± 0.06 g/100g gruel (Fig. 2B). We observed a significant variation in proteins concentrations among millet gruel samples (P = 0.05). This average protein content is four times lower than average protein content found in 'ben-saalga or ben-kida from Burkina-Faso which was of about 8.22 g/100g gruel [4] and did not meet the recommended (13-14 g) level for infants under to 1 year of age [20].

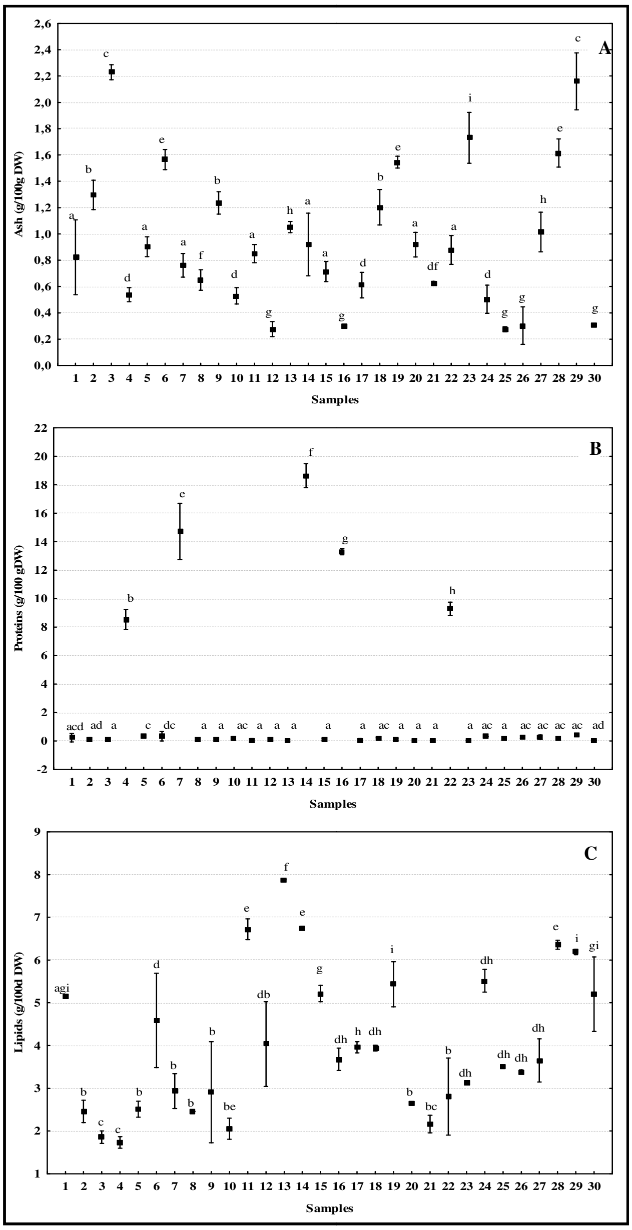

Fig.2. Ash (A), proteins (B) and lipids content (C) of millet gruels sold in Abidjan. Values are presented as means ± SD (n = 2). Means with different letters are significantly different (*P* = 0.05, (Tukey HSD test)

Lipids content of millet gruel samples ranged between 1.73 ± 0.01 g/100g and 7.93 ± 0.05 g/100g gruel with an average value of 4.02 ± 0.80 g/100g gruel (Fig. 2C). We observed a significant variation in lipid concentrations among millet gruel samples (P = 0.05). These results were similar to data found in 'ben-saalga or ben-kida from Burkina-Faso where lipids level ranged between 2.54 and 6.63 g/100g gruel with an average value of 4.69 g/100g gruel [4]. However, the lipid content of millet gruels sold in Abidjan did not meet the range level (10-25 g/100) recommended for children under 1 year of age [20].

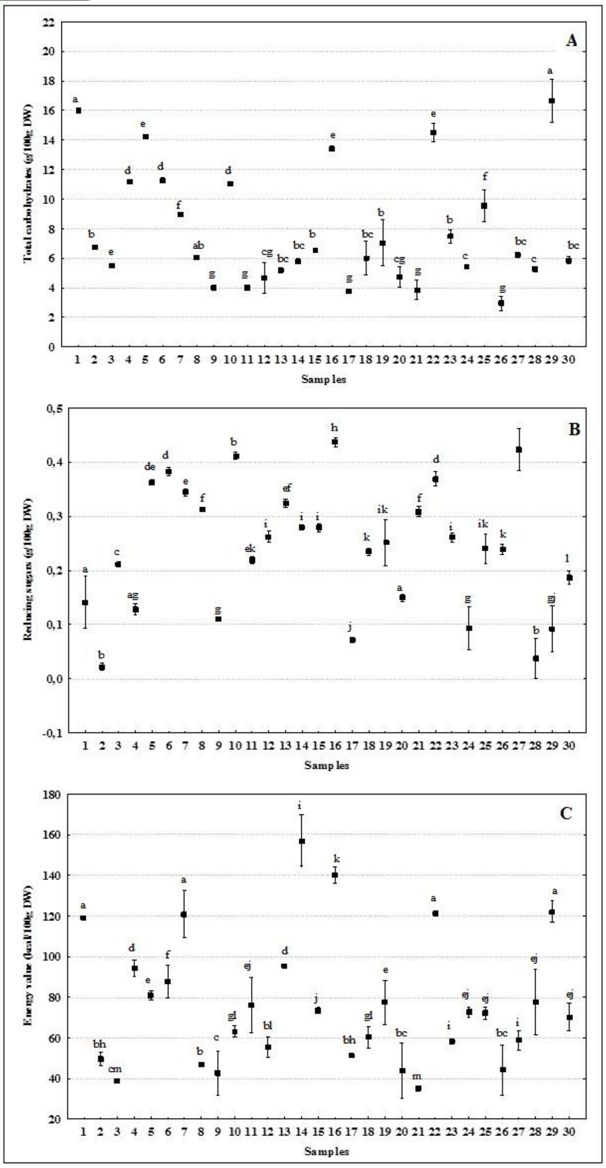

Fig.3. Total carbohydrates (A), reducing sugars contents (B), and energy value content (C) of millet gruels sold in Abidjan. Values are presented as means ± SD (n = 2). Means with different letters are significantly different (*P* = 0.05Tukey HSD test)

Total carbohydrates or reducing sugars content of millet gruel samples ranged between 2.93 ± 0.06 g/100g or 0.02 ± 0.001 g/100g and 16.64 ± 0.16 g/100g or 0.44 ± 0.001 g/100g gruel with an average value of 7.84 ± 0.90 g/100g or 0.24 ± 0.08 g/100g gruel (Fig. 3A, B), respectively. We observed a significant variation in total carbohydrates or reducing sugars concentrations among millet gruel samples (P = 0.05). Millet gruels sold in Abidjan had different levels of both total carbohydrates and reducing sugars. The average total sugars content (7.8 g/100 g DW) of millet gruel is approximately two fold higher than that of ben-saalga or ben-kida from Burkina-Faso which was of about 4.2 g/100 g of sweetened gruel [4]-[25]. Both millet gruels sold in Abidjan and Ouagadougou are added with sucrose before consumption. Millet gruel sold in Abidjan still contained significant levels of sugars, which could not be metabolize during fermentation, but lower than the level (64g/100g) recommended for children under 1 year of age [20]. The level of reducing sugars is overall low and could result from maillard reactions, which occurred during mush cooking.

Energy value of millet gruel samples ranged between 45.18 ± 0.09 Kcal/100g and 157.15 ± 1.41 Kcal/100g gruel with an average value of 77 ± 5.34 Kcal/100g gruel (Fig. 3C). We observed a significant variation in energy values among millet gruel samples (P = 0.05). The average energy value (77 Kcal/100g DW) of millet gruels sold in Abidjan is higher than that of ben-saalga or ben-kida from Burkina-Faso which was of about 47 Kcal/100 g of sweetened gruel [4], but did not meet the energy value level (650 Kcal/100g) recommended for children under 1 year of age [20]. The average proteins (9 Kcal/100g), lipids (36 Kcal/100g) and carbohydrates (31 Kcal/100g) contribution to the average millet gruels energy value is of about 41%, 12% and 47%, respectively. According to recommended nutrient density, a well-balanced weaning food should provide 13.26 and 61% of the total energy from protein, fat and carbohydrates, respectively [26]. We observed an imbalance of energy value from the different nutrients in all millet gruel samples sold in Abidjan, which affected the overall quality of the food. High-energy dense foods are necessary for children to cover their energy needs considering the small size of their stomach [27]. Attention should be paid to the nutritional quality of millet gruels sold in Abidjan since they are used as weaning foods.

Table 1 data show the micronutrient concentrations in the millet gruel samples sold in Abidjan. Iron is an essential micronutrient for the synthesis of hemoglobin (an oxygen carrier in the red blood cells), myoglobin (used for muscle contraction) and enzymes/coenzymes (used in various metabolic pathways). Iron also enhances the body's immune system thus reducing infections and fostering proper functioning of other organs of the body [28]. Iron concentrations in millet gruel samples ranged between 1.37 ± 0.001 mg/100g and 12.77 ± 1.75 mg/100g gruel with an average value of 5.00 ± 0.87 mg/100g gruel (Fig. 4A). We observed a significant variation in iron concentrations among millet gruel samples (P = 0.05). All of the millet gruel samples contained lower concentration of iron than the level (21 mg/100g) recommended for children under 1 year of age [20].

Calcium is an essential micronutrient in infants and young children for building bones and teeth, functioning of muscles and nerves, blood clotting and for immune defense [28]. Calcium concentrations in millet gruel samples ranged between 3.59 ± 0.17 mg/100g and 71.70 ± 1.33 mg/100g gruel with an average value of 24.31 ± 2.12 mg/100g gruel (Fig. 4B). We observed a significant variation in calcium concentrations among millet gruel samples (P = 0.05). All of the millet gruels contained lower concentration of calcium than the level (400 mg/100g) recommended for children under 1 year of age [20].

Magnesium is a micronutrient used for bone mineralization, teeth maintenance, building up of proteins,

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enzyme activities, normal muscular contractions and transmission of nerve impulses Magnesium concentrations in millet gruel samples ranged between 6.40 ± 0.65 mg/100g and 65.43 ± 2.17 mg/100g gruel with an average value of 39.81 ± 1.50 mg/100g gruel (Fig. 4C).

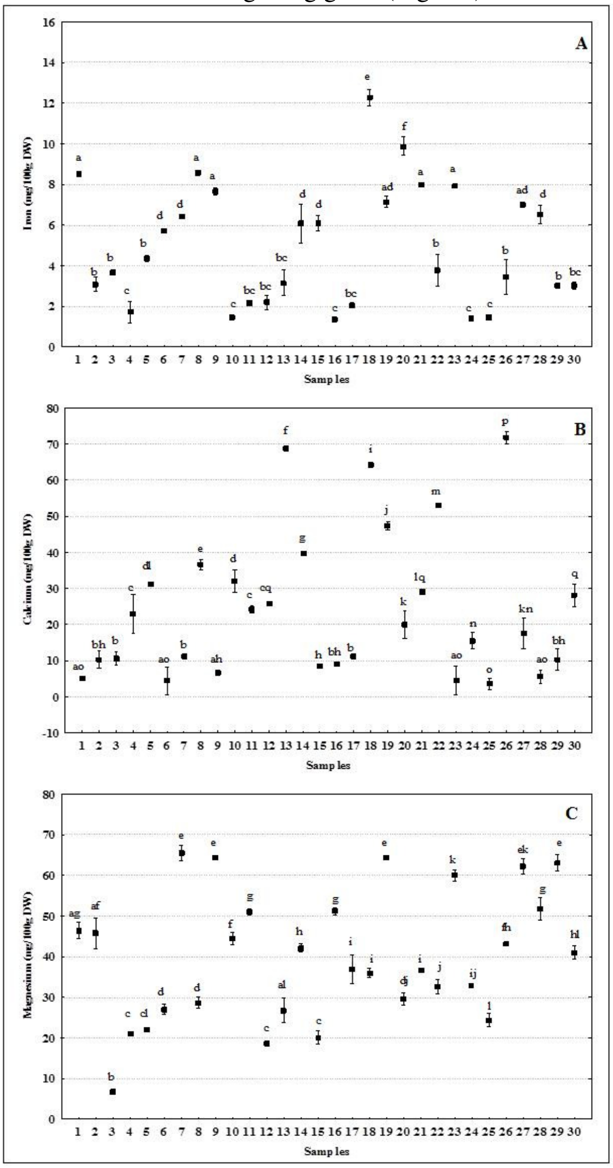

Fig.4. Iron (A), calcium (B) and magnesium content (C) of millet gruels sold in Abidjan. Values are presented as means ± SD (n = 2). Means with different letters are significantly different (*P* = 0.05, (Tukey HSD test)

We observed a significant variation in magnesium concentrations among millet gruel samples (P = 0.05). Only 47 % of samples met the level (40 mg/100g) recommended for children under 1 year of age [20]. A low final mineral content of cereal gruel was the result of significant losses of soluble minerals during cereal grain processing [1]-[4].

We used PCA to assess the patterns of variations by considering all variables simultaneously. The eigen values and variance proportion of the PC as well as the loading plots for twelve proximate variables are presented in Table 2 and Fig. 5, respectively. The first ten PC - axes explained the total variation (100%) within the twelve parameters. The first five axes had eigen values ≥ 1.0 and contributed to 82.65 % of the total variation within the studied variables. The first PC-axis made the highest contribution (30%) to explaining the total variation in the proximate composition. The twelve variables had significant contribution to the variances within each PC-axis. Titratable acidity, pH, energy value, carbohydrate, protein and dry matter contents were the six variables which significantly contributed to the quantity of variance in the PC1. In, PC2, total ash, magnesium and protein contents were most significant; while calcium content was significant for PC3. Iron and lipid contents were the two significant variables in PC4. In the last PC-axis, carbohydrate content and titratable acidity value were significant in their impact in determining the variance within the PC-axis. Titratable acicidity and protein contents consistently featured in two PC-axes and could be parameters which affect significantly the proximate composition of millet gruels.

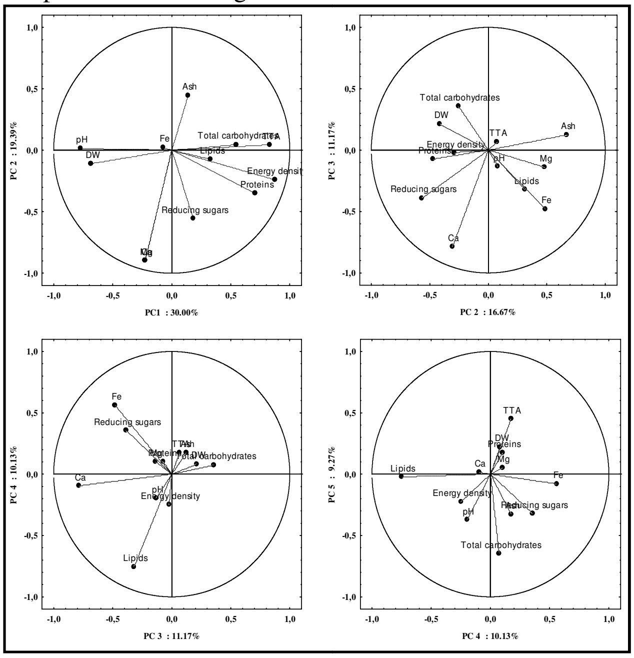

Fig.5. Loadings of twelve proximate parameters on principal axes 1, 2, 3, 4 and 5. Mg: magnesium, Ca: calcium, TTA: titratable acidity, DW: dry weight

Significant variability in millet gruel pH, titratable acidity, and dry matter values, ash, macronutrient (proteins lipids, carbohydrates), micronutrient (iron, calcium, magnesium) content or energy value could be due to differences in processing conditions between gruel sellers of Abidjan or composition of millet grains. The use of dehydrated starter culture could be envisaged during processing of Ivorian fermented products [2]. The direct addition of selected starter cultures during traditional foods processing could result in the standardization of the end product [29].

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Table 2: Eigen vectors and variance proportion of twelve proximate variables in ten PC-axes

Proximate composition	Eigen vectors									
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Dry matter	-0,68	-0,11	-0,49	-0,01	-0,21	-0,29	0,08	0,01	-0,37	-0,06
pH	-0,77	0,02	0,02	-0,13	0,43	0,30	0,25	0,13	0,11	-0,12
Titratable acidity	0,83	0,04	0,08	0,09	-0,49	-0,07	-0,05	-0,08	0,10	-0,15
Total ash	0,14	0,44	0,56	0,28	0,22	-0,45	0,01	0,38	-0,04	-0,02
Proteins	0,71	-0,35	-0,28	0,07	-0,17	0,19	0,37	0,30	-0,04	0,03
Lipids	0,33	-0,07	0,58	-0,65	0,13	0,13	-0,19	-0,02	-0,23	-0,02
Carbohydrates	0,55	0,05	-0,31	0,14	0,63	-0,28	0,09	-0,30	0,01	-0,02
Reducing sugars	0,18	-0,56	-0,28	0,42	0,27	0,21	-0,50	0,18	-0,07	-0,03
Energy value	0,88	-0,24	-0,07	-0,19	0,27	0,04	0,19	0,03	-0,13	-0,00
Iron	-0,07	0,02	0,60	0,65	-0,03	0,30	0,19	-0,21	-0,20	0,00
Calcium	-0,23	-0,90	0,30	-0,01	-0,02	-0,21	0,07	-0,04	0,07	-0,00
Magnesium	-0,23	-0,90	0,30	-0,01	-0,02	-0,21	0,07	-0,04	0,07	-0,00
Eigen value	3.60	2.33	1.68	1.20	1.11	0.74	0.58	0.43	0.29	0.05
% variance	30.00	19.39	14.03	9.98	9.26	6.13	4.82	3.56	2.44	0.38
Cumulative variance	30.00	49.38	63.41	73.39	82.65	88.79	93.61	97.17	99.62	100.00

Table 3: Microbiological quality of millet gruels sold in Abidjan compared to microbiological criteria

Group of microorganisms	Microbiological crireria		Results for millet mush samples analyzed [a]	
	Limits (cfu/g)	Standards concerned	Count values (cfu/g dry weight)	Proportion of samples outside limits (%)
TAMF	3×10^5	[30]: count of TAMF	$0 \leq x \leq 2\times10^6$	6.7 (2/30)
TC	1×10^3	[34]: count of CT	0	0 (0/30)
THC	1×10^1	[34]: count of THC	0	0 (0/30)
Yeasts	1×10^2	[31]: count of yeasts	$0 \leq x \leq 4\times10^2$	6.7 (2/30)
Moulds	1×10^2	[31]: count of moulds	0	0 (0/30)

a Results for 60 samples
TAMF: total aerobic mesophilic flora, TC: total coliform, THC: thermotolerant coliform

B. Microbiological quality

The total Aerobic Mesophilic Flora (TAMF), Total Coliform (TC), Thermotholerant Ccoliform (TC), yeast and mould counts (cfu/g Dry Weight) as well as the percentage of corrupted millet gruel samples (according to the recommended limits) are summarized and highlighted in Table 3, respectively**.** The TAMF flora ranged from 0 to 2×10^6 (cfu/g DW) (Fig. 6A) and only 6.7 % of samples were outside of the recommended limits [30]. The yeast counts ranged from 0 to 4×10^2 (cfu/g DW) (Figure 6B) and only 6.7 % of samples were outside of the recommended limits [31].

Both the TAMF flora and yeast counts were significantly different among millet gruel samples (P = 0.05). No coliforms, thermotolerant coliforms and mould species were detected in the samples. Ref. [32] and [33] showed, respectively, that the microbiological quality of millet and sorghum gruels consumed as weaning foods in Ouagadougou (Burkina-Faso) and in the Gauteng Province (South-Africa) is poor with coliform counts (zero values or below the lower detection limit) after cooking. The low rate of millet gruels outside of the limits, the absence of fungi and indicators of poor hygiene and possible contamination with microorganisms of fecal origin could be explained by the destruction of most of the microorganisms by heat during cooking.

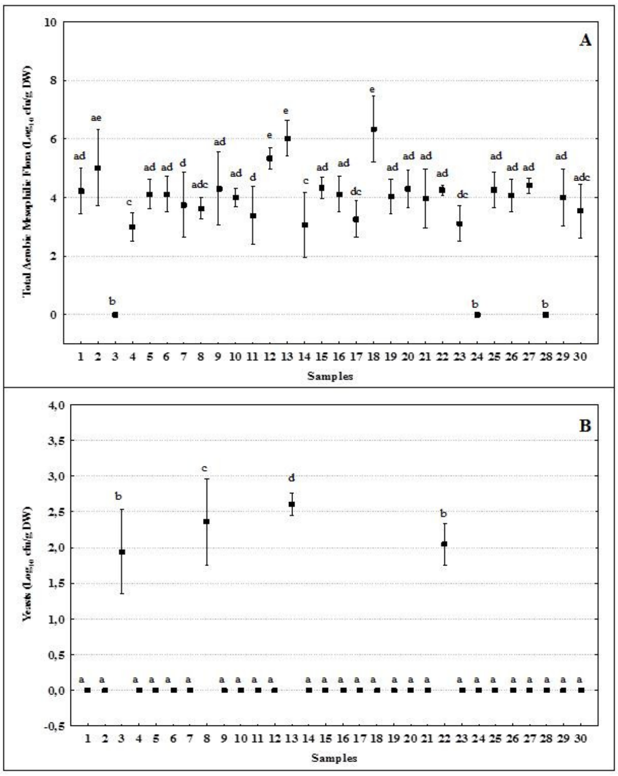

Fig.6. Total Aerobic Mesophilic Flora (A) and yeast (B) counts of millet gruels sold in Abidjan. Values are presented as means ± SD (n = 4). Means with different letters are significantly different (*P* = 0.05,Tukey HSD test)

During cooking of millet gruels sold in Abidjan, heat treatment could be sufficient to reduce or limit microbial contamination. Moreover, the preservative role of lactic fermentation technology had been confirmed in cereal products.

IV. Conclusion

We observed significant variations in proximate composition and microbiological quality among millet gruels sold in Abidjan. Despite an overall acceptable microbiological quality, the macronutrient (proteins lipids, carbohydrates) and micronutrient (iron, calcium, magnesium) contents as well as energy value of millet gruels were even further below recommended levels for children under 1 year of age. For instance, the use of millet gruels as weaning foods may be a risk factor for macro/micronutrient deficiency disorders among infants. More efforts must be directed towards the supplementation of the starchy food with protein and mineral rich foods as well as the use of dried starter culture during millet gruel processing. A better control of fermentation process, standardization and improvement of the end product could be achieved.

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