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Research Article
Microbiological, Nutritional and Sensory Characteristics of the Foodstuff "*Foura*" Produced From Millet in Benin

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Abstract
Objective: The objective of study was to develop a good quality "*Foura*" in order to ensure the safety of consumers. **Materials and Methods:** A survey was conducted in the districts of Cotonou, Kandi and Malanville which are considered to be areas of high production and consumption of "*Foura*". Microbiological, nutritional and sensory analysis were carried out of the unfermented "*Foura*" sold on the market and the fermented and unfermented "*Foura*" that we produced. A sensory analysis was performed after production. **Results:** The results of the survey showed that the production technology of the "*Foura*" is dependent on the empirical knowledge of the producers. Microbiological analysis revealed that unfermented "*Foura*" sold in the market contained thermotolerant coliforms, *E. coli*, yeasts, sulphite-reducing bacteria in excess of set limit values. On the other hand, the unfermented and the fermented "*Foura*" that we produced are of satisfactory hygienic quality because they do not contain thermotolerant coliforms, ASR, or *E. coli*. Nutritional analysis showed that unfermented "*Foura*" sold in market and the unfermented one produced contained proteins (3.77 and 2.81%), total sugars (3.29 and 2.82%), fats (5.08 and 4.23%), iron (2.10 and 2.71 mg) and an energy value (73.96 kcal/100 g and 60.5 kcal/100 g) respectively. However, the fermented "*Foura*" is richer in iron (3.09 mg) protein (7.13%), fat (5.93%), energy value (90.85 kcal/100 g) and more appreciated by the tasters. **Conclusion:** Fermented and non-fermented "*Foura*" produced from millet are rich in nutrients and provide the body with a very appreciable energy value.

Key words: Millet, milk, fermentation, "*Foura*", nutritional quality, cassava processing, complementary food

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cereals cultivation around the globe have indicated different geographical areas regarding specific food and culture. Throughout, Africa, fermentation is a traditional part of cereal and cassava processing[1]. Some of these traditional cerea1-based fermented gruels are frequently used as complementary foods for infants and young children[2]. They include maize, millet, sorghum, wheat, barley, rice, oats and rye and present a variety of species that feed a large population around the globe. Millet cultivation in general dates back to ancient times. Ranked as the sixth most cultivated cereal in the world[3], millet (*Pennisetum glaucum*) or pearl millet or small millet is a group of annual food grasses that share the common characteristic of small grains. In Africa, 70% of the production comes from the West of the continent. It plays a major role for local populations in regions where climatic conditions do not allow sorghum, maize or rice to grow normally[4]. It is a major source of carbohydrates, proteins, vitamins and minerals for population[5]. Different techniques have been developed for producing variety of foods from millet depending upon the area. In West Africa, millet is often consumed in the form of cooked dough such as tô in Burkina-Faso and porridge such as *ben-kida*, *bensalga* and *kirario*[6,7]. It is also used in the manufacture of alcoholic beverages such as millet beer or dolo in Burkina Faso[8] or non-alcoholic beverages such as kokosour water, obiolor, kunun-zaki[9-11] or used in the production of lumps and milk foods such as *dèguè*, *tchobal* or *foura* and *gappal*[12-15]. Millet grains are excellent sources of dietary protein due to their significant fiber content. However, the nutritional and sensory quality of millet and its processed products remain slow compared to that of milk, also widely consumed in Africa. Milk has a higher content of total protein, essential aminoacids (lysine) and vitamins. The digestibility of calcium and phosphorus is exceptionally high in milk, partly because they are found in association with casein[16]. Therefore, the addition of milk to millet significantly increases the nutritional quality of the feed. The stage of adding milk to millet to enhance the nutritional and sensory quality of foods varies by product and by locality. Millet balls called "*Foura*" are products obtained by mixing millet flour with water. They are cooked in boiling water and after crushing the balls are reformed. "*Foura*" is consumed with milk, sugar and ice and is an energy drink that is widely consumed in Benin as well as in other regions. "*Foura*" is sold throughout Benin, where it is consumed most in the northern region during the Lenten season and hot weather. Mostly produced by non-literate women, it is prepared with out any rules of hygiene and good production practices. Moreover, it is a food that is widely consumed by a given mass of individuals and little known by the general population. The consumption of "*Foura*" might be due to lack of knowledge and popularization of the nutritional value of this food. Faced with this, we have decided to carry out this study to analyze the microbiological, nutritional and sensory characteristics of "*Foura*".

MATERIALS AND METHODS

Plant material: The plant material used was millet (*Pennissetum glaucum*) which was purchased from the international market of Dantokpa (District of Cotonou, Republic of Benin).

Production material: The production equipment used was basins, a scale, a tray, a plastic bucket, a pot, a spoon, a gas stove, a mill, a cup, an apron, a strainer, a mortar, a pestle and water from the SONEB (National Water Company of Benin).

Laboratory material: The classic laboratory equipment was used for the various microbiological and physicochemical analyses.

Methods: The experiment consisted of the production of unfermented and fermented "*Foura*" according to the technological diagram of survey. The samples were collected aseptically in stomacher bags. These samples were carefully named with all necessary information and transported directly to the laboratory in a cooler containing dry ice for the various analyses. The manufacturing technologies of unfermented and fermented "*Foura*" are presented in Fig. 1 and 2.

Microbiological analysis: Microbiological analysis focused not only on the search for pathogenic microorganisms but also on germs indicative of good hygiene practices in food industry[17]. The culture media were prepared according to the manufacturer's instructions and maintained in super cooled until the time of inoculation except Baird Parker Agar (BPA) enriched with egg yolk and potassium tellurite which was pre-poured into a Petri dish. To prepare the stock solution, 10 g of eachsamplewastakenwith a sterile spatula in a sterile stomacher bag and 90 mL of tryptone salt broth was added. This mixture washomogenized in a sample mixer. Successive decimal dilutions were made from the stock solution. The inoculation wasperformedusing mass inoculation technique except for BPA which was inoculated on the surface. Total bacteria was counted on the Plate Count Agar (PCA) after incubation at 30°C for 72 h$\pm$2 h[18], the total coliforms on the

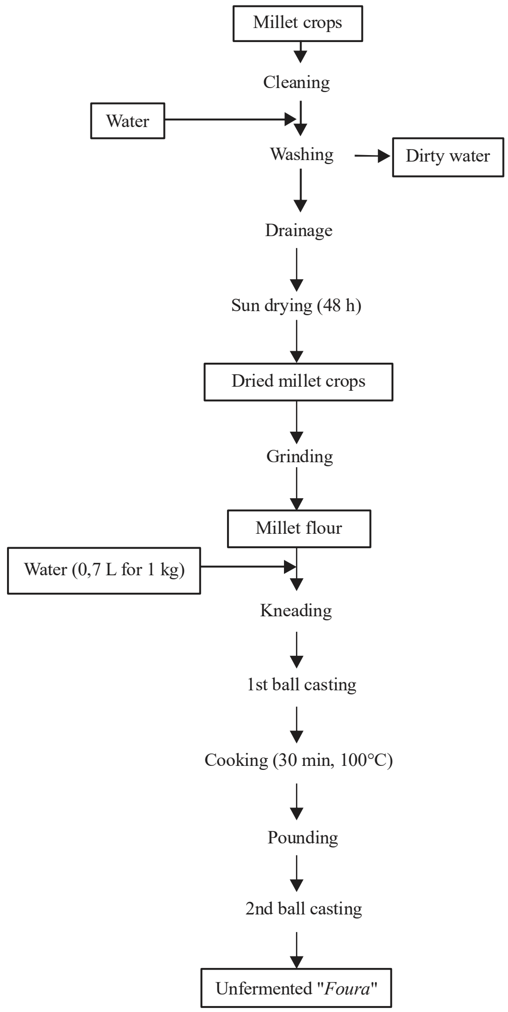

Fig. 1: Technological diagram of the production of unfermented "*Foura*"

Violet Red Bile Glucose (VRBG) after incubation at 30°C for 24 h±2 h[19], the thermo tolerant coliforms on VRBG at 44°C for 24±2 h[20], staphylococci on BPA with egg yolk and potassium tellurite after incubation at 37°C for 48 h±2 h[21]. The search for *Escherichia coli* β-glucuronidase was carried out using coliform dishes on Violet Red Bile Lactose Agar (VRBLA) by performing the Mac-Kenzie test (indole and oxidase) using Kovacs and oxidase reagents[22]. The enumeration of the anaerobicsulphito-reducing bacteria was carried out on Tryptone Sulfite Neomycin Agar (TSNA) after incubation at 46°C for 20 h±2 h[23]. Finally, the search for salmonella was carried out on Salmonella Shigella Agar (SSA) according to standard ISO 6579-1[24]. The microbiological analysis were carried out in three repetitions on each sample. As for yeasts and molds, they were counted on OGA agar enriched with oxytetracycline after incubation at 25°C for 3-5 days[25]. Microbiological analyses were performed in three repetitions on each sample. The number of germs was expressed in Colony Forming Units per gram (CFU g^{-1}).

Physico-chemical analysis: The physico-chemical parameters investigated were dry matter, water, ash, protein, lipid, carbohydrate (total sugar), iron and pH. Thus, the water content and the dry matter content were determined as described by AACC[26]. The protein content (N×6.25) was determined by the Kjeldahl method according to AACC[26]. The pH was measured using an electronic probe pH meter that was previously calibrated with buffer solutions of pH7 and pH4 at 2°C. This measurement was taken on 25 mL of the sample. The total sugar content was determined according to the method of Dubois *et al.*[27]. The ash was determined according to the method described by AACC[26]. Iron (Fe) was

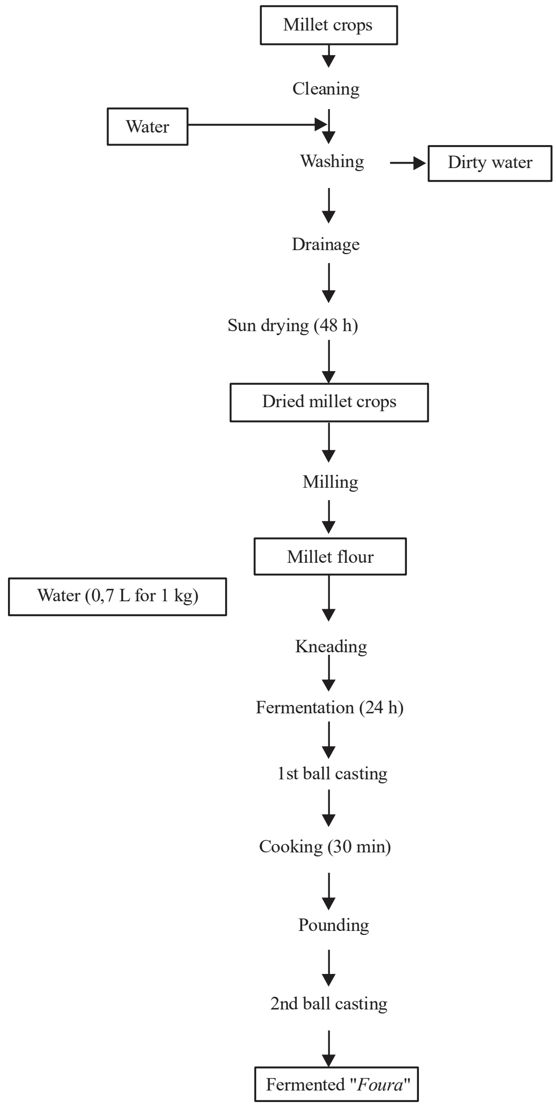

Fig. 2:Technologicaldiagram of fermented *"Foura"* production

determined by atomic absorption spectrophotometry (AAS) after mineralization of the formulations[13]. The fat content of the samples was determined by Soxhlet extraction according to the international standard[26]. The energy value was estimated using Atwater's coefficients[28] which express the amounts of kilocalories provided by:

$$\text{VE (kcal/100 g)} = 4\times\text{Proteins (\%)}+4\times\text{Carbohydrates (\%)} +9\times\text{Lipids (\%)}$$

Sensory evaluation: The sensory evaluation was carried out to assess the different organoleptic characteristics of the different "*Foura*" produced. A panel of 20 analysts assessed the different parameters namely: color, taste, acidity, smell (aroma) texture and overall acceptability. This was done on a scale of 1-9 with: 1= Extremely inferior, 2 = Very inferior, 3 = Moderately inferior, 4 = Slightly inferior, 5 = Identical to the reference sample, 6 = Slightly better, 7 = Moderately better, 8 = Better and 9 = Extremely better[13,29].

Statistical data analysis: Data were analyzed using one-way analysis of variance (ANOVA). All statistical analyses were performed using the Statistical Package for Social Science (SPSS) version 16.0 for windows (SPSS Inc., Chicago, IL, USA). Differences of $p<0.05$ were considered statistically significant.

RESULTS AND DISCUSSION

Microbiological characteristics of "*Foura*": Table 1 shows the results of the microbiological analyses carried out on the various "*Foura*".

Table 1: Microbiological quality of "*Foura*"

	FT (CFU g^{-1})	CT (CFU g^{-1})	CTh (CFU g^{-1})	*E. coli* (CFU g^{-1})	Staph+ (CFU g^{-1})	Sal (CFU g^{-1})	ASR (CFU g^{-1})	L (CFU g^{-1})	M (CFU g^{-1})
"*Foura*" sold on the market	3×10^6	$3.7.10^3$	$2.5.10^2$	10^2	$7.6.10^2$	Abs	10	1.5×10^4	1.2×10^2
Fermented "*Foura*"	5×10^4	Abs	Abs	Abs	Abs	Abs	Abs	5.3×10^2	1.8×10^2
Unfermented "*Foura*"	2.4×10^3	Abs	Abs	Abs	Abs	Abs	Abs	70	20
Criteria	10^5	10	1	Abs	Abs	Abs	Abs	10^3	10^3

FT: Total flora, CT: Total coliforms, CTh: Thermotolerant coliforms, *E. coli*: *Escherichia coli*, Staph+: Coagulase-positive staphylococci, ASR: Anaerobic Sulfito-Reducers, Sal: Salmonella, L: Yeasts, M: Molds, CFU g^{-1}: Colony forming unit per gram

Table 2: Physico-chemical and nutritional characteristics of *"Foura"*

Parameters	Unfermented "*Foura*" sold	Unfermented "*Foura*" produced	Fermented "*Foura*" produced
Dry matter (%)	80.81±0.97	70.47±1.18	64.49±1.87
Quantity of water (%)	19.18±0.97	29.52±1.18	35.51±1.87
pH	4.91±0.75	4.65±0.01	3.02±0.04
Proteins (%)	3.77±0.75	2.81±0.12	7.13±1.10
Total sugars (%)	3.29±0.10	2.82±0.03	2.24±0.01
Lipids (%)	5.08±0.01	4.23±0.03	5.93±0.01
Ashes (%)	1.06±0.01	0.67±0.11	1.18±0.18
Energy (kcal/100 g)	73.96±1.45	60.67±0.02	90.85±1.05
Iron (mg/100 g)	2.10±0.04	2.71±0.02	3.09±0.03

Table 1 shows that for all the germs investigated, the "*Foura*" sold in the market contained higher microbial load than the acceptable level of hygiene criteria. On the other hand, the microbial loads obtained in the samples of the fermented and non-fermented "*Foura*" produced were lower than the fixed limit values. The microbiological quality of "*Foura*" sold in the market was unsatisfactory while the fermented and unfermented "*Foura*" produced were of satisfactory quality. The presence of coliforms and *E. coli* in the samples of "*Foura*" sold in the market can be explained by a fecal contamination due to water used by the producers or poor hygiene practices during the production and the marketing. Similar results were reported by King *et al.*[30] and Baba-Moussa *et al.*[31] who observed contaminated food sold in streets due to poor transportation. The high loads of total flora, yeasts and molds, the presence of coagulase-positive staphylococci and sulfito-reducing anaerobes in the "*Foura*" sold in the market reflects the non-compliance of good hygienic practices during production and marketing. Célestin *et al.*[32] also reported that the environment in which these products are handled is the main source of these germs. On the other hand, the absence of coliforms, *E. coli*, coagulase-positive staphylococci and sulfite-reducing anaerobes in the samples of fermented and non-fermented "*Foura*" produced reflects the respect of good hygiene practices during production. Similar observations were made by Jultesse *et al.*[33] and Tchekessi *et al.*[34] who reported that the absence of these germs indicate the acceptable level of hygiene during food production. Moreover, presence of coliforms in food is indicative of fecal contamination after heat treatment and poor hygienic condition during production. The high loads of total flora, yeasts and molds in fermented "*Foura*" samples as compared to unfermented "*Foura*" produced is due to fermentation. The same observation was made by Lei and Jakobsen[35]; Greppi *et al.*[36] who reported that spontaneously fermented cereal-based pasta in Africa was an important source of lactic acid bacteria and yeast.

Physicochemical and nutritional characteristics of "*Foura*": Table 2 shows the physico-chemical and nutritional characteristics of the "*Foura*".

Table 2 shows that the fermented "*Foura*" produced contained more protein, iron and ash than the unfermented "*Foura*" sold in the market and the one produced. Similarly, its energy, water and fat content were higher than those of the other two unfermented "*Foura*". On the other hand, its total sugar content was lower than those of the other two unfermented "*Foura*". These observations can be explained by fermentation, which is a biochemical process that allows the enrichment of the medium with nutrients through the action of microorganisms (yeasts, lactic bacteria) on the sugar contained in the medium. Similar observation was made by Mugula *et al.*[37] and Tchekessi *et al.*[38]. Fermented foods have extended shelf-life, improved palatability, digestibility, nutritive value, texture, taste and aroma resulting from the activity of the microorganisms involved[39,40]. Note that the pH of the fermented "*Foura*" was less than 4, this had inhibited the development of pathogenic microorganisms whose optimal pH for growth is above 4.5[34,41]. This is not the case for the two non-fermented "*Foura*" whose pH was above 4.5.

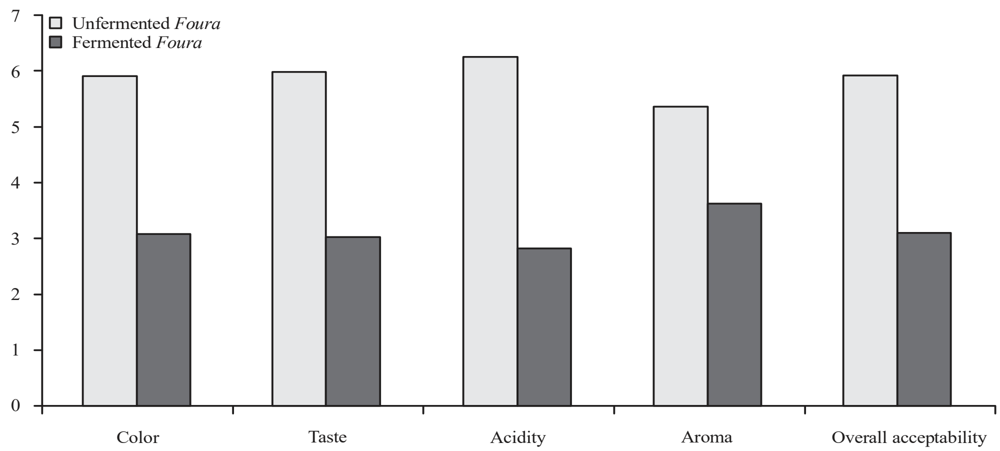

Fig. 3: Comparison of the sensory parameters of the two types of "*Foura*" (fermented and non fermented) diluted with fermented milk

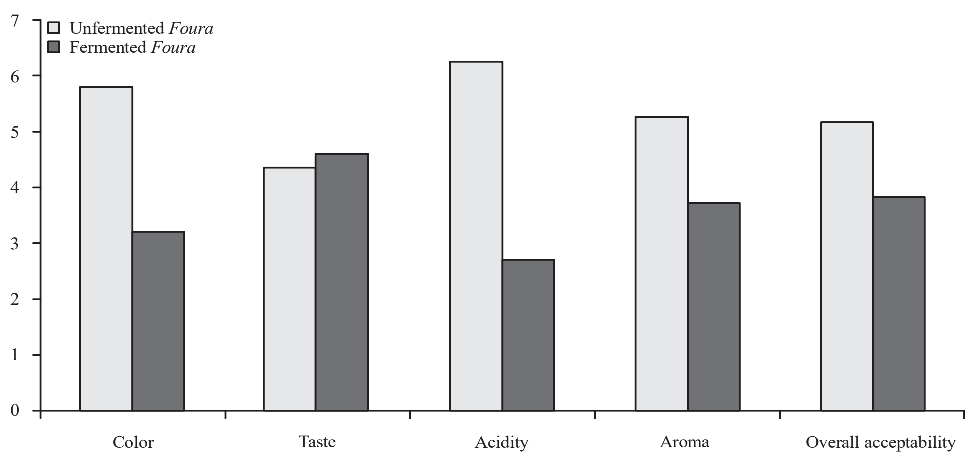

Fig. 4: Comparison of the sensory parameters of the two types of "*Foura*" diluted with non-concentrated milk

Sensorial characteristics of fermented and non-fermented "*Foura*" produced: Figure 3 illustrates the comparison of the sensory parameters of the two types of fermented and non-fermented "*Foura*" produced diluted with fermented milk. Figure 3 reveals that the fermented "*Foura*" diluted with fermented milk was globally more accepted in terms of color, taste, aroma and acidity than the unfermented "*Foura*" produced. In fact, it was found that more food tasters preferred the fermented "*Foura*" than the unfermented one. This can be explained by the fact that fermentation improves the sensory characteristics of product[32,42]. Figure 4 shows the comparison of sensory parameters of the two types of "*Foura*" diluted with non-concentrated milk.

Figure 4 shows that fermented "*Foura*" diluted with non-concentrated milk was more appreciated by the tasters in terms of color, aroma and acidity than unfermented "*Foura*" diluted with non-concentrated milk. On the other hand, its taste was slightly less appreciated than that of the unfermented "*Foura*". These findings depicted the taste of non-concentrated milk used.

CONCLUSION

The present study has made it possible to develop a good quality fermented "*Foura*" and to characterize the production technology. The technology for production of "*Foura*", exclusively made by illiterate women in the field, depends on the empirical knowledge of the women producers. This knowledge is a heritage which is passed on from generation to generation. "*Foura*" is consumed in several West African countries such as Nigeria, Mali, Niger, Burkina Faso and throughout Benin, particularly in the North by the Dendi, Hausa, Bariba and German people. Fermented and non-fermented "*Foura*" produced from millet are rich in nutrients (carbohydrates, lipids, protein, iron, etc.) and provide the body with a very appreciable energy value. "*Foura*" can be recommended to people of all ages (children, young people, adults and the elderly) for good health.

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