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Controlling the Traditional Fermentation Process for the Production of “attiéké” in Dabou (Côte d’Ivoire)

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Abstract

Introduction: “Attiéké” plays a crucial role in the daily lives and diets of many communities in Côte d'Ivoire. However, the national market offers a wide variety of “attiéké” qualities, which affects the uniformity of its production. One of the main causes of this variation is poor control of the fermentation parameters. **Objective:** The aim of this study was to standardise attiéké production by optimising fermentation, focussing on ferment control, the rate of incorporation, and fermentation time, to guarantee consistent quality. **Methods**: To this end, “attiéké” samples were prepared from fermented doughs containing 8%, 10% and 12% inoculum, with fermentation periods of 0, 6, 12 and 24 hours. These samples were then compared with a reference “attiéké” produced in Dabou. The effectiveness of standardising fermentation parameters was assessed by measuring microbial loads of lactic acid bacteria, *Bacillus*, yeasts, and moulds, and by analysing physicochemical parameters such as pH, glucose, sucrose, fructose, lactic acid, acetic acid and ethanol. **Results**: The results showed that the fermentation that produced an “attiéké” similar to the control sample was carried out with 10% ferment for 12 hours (C10T12). This “attiéké” showed *Bacillus* loads of 2.6 log10 cfu/g, lactic bacteria loads of 1.1 log10 cfu/g, as well as a glucose concentration of 6.35 g/L, sucrose of 4.8 g/L, lactic acid of 4.45 g/L, acetic acid of 1.35 g/L, and a pH of 4.8. **Conclusion:** Therefore, this work answers the question of the reproducibility of this traditional dish, “attiéké”.

Keywords: “Attiéké”, cassava paste, fermentation, standardisation, microbial load, physicochemical parameters

1. Introduction

“Attiéké” is the product derived from the processing of stale cassava. “Attiéké” is a foodstuff that is widely consumed in urban areas (Alamu et al., 2019). It is gradually making its way to Europe, America, and Asia thanks to the migration of populations through the black African diaspora (Kakou, 2000).

In Côte d'Ivoire, “attiéké” plays a major role in family diets due to its many and varied uses (Assanvo *et al.*, 2006; Trazié, 2019). It accounts for around 5% of food expenditure and 70% of calories in the diets of people who eat it. For the people of the coastal region, which are recognised as the main producers and consumers, ‘attiéké’ is the main source of income-generating activity. With 45000 tonnes and an annual turnover of 70 billion, it is the most widely consumed cassava-based food in Côte d'Ivoire (CSRS, 2016). Annual consumption represents 21.5% of the national population (RGPH, 2021). In terms of sales, ‘attiéké’ appears to occupy an important place in the local marketing of foodstuffs, alongside roots and tubers (such as cassava and yams) and cereals (such as rice and maize) in most markets in Côte d'Ivoire and the West African subregion (FAO, 2004; FAO, 2006).

Despite this reputation in the local diet, food preparation is largely informal. It is based on traditional experience

rather than scientific knowledge (Essers et al., 1993; Mosso et al., 2000). However, it has always been thought that the quality of attiéké could be improved by mastering (and/or automating) processes such as fermentation, pressing, and semoulage. Producers consider these stages to be fundamental.

In this study, the focus is on the control of fermentation from a technical point of view. The identification of magan or lidrou microorganisms involved in the fermentation stage has been the subject of several studies (Coulin et al., 2006; Djeni et al., 2011; Assanvo et al., 2017; Assanvo et al., 2019; Kpata-Konan et al., 2020). In the manufacture of "attiéké", ferment known as lidjrou (among adjioukrou) or magnan (among Ebrié) is added to the grated cassava paste in varying amounts and quality to initiate fermentation of the grated cassava paste. Generally, this operation depends on the operator who wants to speed up and direct the fermentation process of the grated cassava paste. This is a crucial stage, but unfortunately one that not all attiéké producers have mastered. The number of ferments incorporated and the duration of fermentation of the grated cassava paste vary according to the sensitivity of the operator (Assanvo et al., 2017).

To monitor fermentation in the semiindustrial environment, pH strips are used (Assanvo et al., 2017). This method does not give satisfactory results in fermentation control, as it only measures pH, but not the softening of the grated cassava paste during fermentation. It should be noted that the semiindustrial fermentation process has just as many limitations as the traditional process and would benefit from improvement. In a processing sector largely dominated by traditional methods, the use of a pH metre is almost non-existent. An approach to controlling the concentration/fermentation time relationship is, therefore, essential.

The general aim of this study is to standardise attiéké production by optimising fermentation, focussing on ferment control, the rate of incorporation, and fermentation time, to guarantee consistent quality.

2. Methods

2.1 Materials

Fresh and healthy '*Manihot Esculenta* CRANTZ' cassava roots of the bitter IAC variety (Improved African Cassava) constituted the main plant raw material of the plant used for the study of fermentation, pressing and granulation of grated cassava. These cassava roots were matured (12 months), in the agricultural stations of the Nangui Abrogoua, Côte d'Ivoire. Tuberous cassava roots weigh between 100 and 1000 g.

2.2 Fermentation Preparation

Cassava roots (approximately 500 g each) were collected, peeled, and cooked completely in boiling water (100°C) for 45 min, followed by cooling to ± 25°C at room temperature for 30 min. The cassava roots were then packed completely in a polypropylene jute bag. The cassava and jute bag were then placed in a container with a lid and stored in a confined atmosphere for 36 hours. The traditional ferment thus obtained was cleaned of mould and then rinsed with tap water.

2.3 Preparation of the Cassava Paste

Cassava roots (approximately 5280 g) were harvested, peeled, washed, cut, and reduced into pieces. The obtained pieces were grated to make the cassava dough. The cassava was grated using an electric hammer mill (TDA, Côte d'Ivoire) fitted with a 2 mm diameter metal sieve. A quantity of 4500 g of cassava dough was sampled in 3 batches of 1500 g each, mixed with 0.8% (w/v) bleached palm oil after heating at 100 ° C for 5 min.

2.4 Fermentation

The ferments were inoculated in the 3 batches of 1500 g of cassava dough in different proportions (8%, 10% and 12%). The inoculated dough was left to ferment for 6, 12 and 24 hours at room temperature (25 ± 2°C) in a covered pot. Samples of cassava paste were taken during fermentation (along with the corresponding attiéké) for microbiological and physicochemical analysis. The results obtained are the average of 3 repetitions.

2.5 Preparation of "attiéké"

Once fermentation is complete, the fermented pasta is wrapped in a clean cloth and carefully pressed individually to extract the water. After dehydration, the fermented pasta is shaped into small balls. The balls formed are then dried in the shade for 10 minutes and steamed in a steamer for 30 minutes. After cooking, the attiéké is removed from the steamer, cooled, and packed in stomacher bags. The attiéké produced in comparison with the attiéké from Dabou was used as samples for microbiological and physicochemical analyses. The attiéké produced in the Dabou area is known for their good quality.

2.6 Microbiological Analysis of Cassava Paste and "attiéké"

To isolate the microorganisms, 10 g of each cassava and "attiéké" ferments were added to 90 ml of sterile buffered peptone water in a stomacher bag (AES laboratory, France). The mixture was stirred for 1 minute. The resulting suspension was considered the parent suspension. Then, successive decimal dilutions were made to 10-6 with 9 mL of sterile peptone water. Yeasts and moulds were counted according to FN ISO 6611: 2004 on Sabouraud's chloramphenicol agar, lactic acid bacteria according to ISO 15214: 1998 on Man Rogosa Sharpe agar and Bacillus according to the method described by Buttiaux et al. (1974) on PCA agar. Microbial loads were expressed in CFU / g (colony-forming units per gramme).

2.7 Physicochemical Analysis of Cassava Paste and "attiéké"

2.7.1 Hydrogen Potential (pH)

The pH was determined using a Hanna-type pH metre (HI991001, Romania) (AOAC, 1990). The instrument was calibrated using two buffer solutions at pH 7.0 and 4.0, and this was done systematically prior to pH measurements.

2.7.2 Determination of Organic Acids

The determination of the organic acids in each sample was carried out according to the method of Saska and Zapata (2006), using a high-performance liquid chromatograph (Shimadzu Corporation, Japan) consisting of a pump (Shimadzu LC-20A liquid chromatograph) and a UV detector (Shimadzu SPD-20A UV spectrophotometric detector). All separations were carried out in an isocratic mode. The chromatographic separation of the organic acids was carried out using an ICSep ICE ORH-801 ion exclusion column (40 cm x 5 µm, Interchom, France) maintained at 35 ° C using a Meta ThermTM oven (Interchrom, France). The eluent was sulfuric acid (0.004 N). The elution flow rate was 0.6 ml/min. The detector was selected at 210 nm. A 20 µl aliquot of the previously obtained was injected. The peaks on the HPLC chromatogram were identified by comparison with those obtained with the standards and on the basis of the retention time of the molecules analysed. The peak areas were automatically calculated from reference solutions of known content.

2.7.3 Determination of Sugars

The determination of glucose, fructose and sucrose in each sample was carried out according to the method of Wang et al. (2021), using a model 600 high-performance liquid chromatograph (Waters, USA) with a model 24 refractive index detector. The sugar in the samples was extracted in purified water and then filtered through a 0.45 µm membrane filter. A series of standard solutions of glucose, fructose, and sucrose of 1%, 3%, 6%, 9% and 12% (w / v) were prepared for the development of sugar standard curves. All of the standard solutions were dissolved in distilled water. They were then filtered using a 0.45 µm Millipore membrane filter. The amount of glucose, fructose, and sucrose in the samples was quantified by comparing the area of the peaks.

2.7.4 Ethanol Determination

The ethanol content of the samples was determined using an Agilent 6890N capillary gas chromatograph connected to an Agilent G5977 mass spectrometer and a PAL 3 autosampler. The method used was that of Tsenang et al. (2023). Separation was carried out on a standard DBALC1 bipolar capillary column (30 m long, 0.32 mm internal diameter and 0.25 µm film thickness). The injections were carried out in fractionated mode using a general-purpose sheath, with or without fractionation, filled with glass wool. The gas chromatography oven temperature programme was started at 35 ° C and held for 2.5 minutes, then increased to 90 ° C at a rate of 10 ° C min-1 and held for 4 minutes, then increased to 220 ° C at a rate of 10°C, giving a total run time of 23 minutes. Sample volumes of 1 µL were injected into the instrument in a 50:1 split ratio using helium as the carrier gas. The helium flow rate was set at a constant of 0.5 ml min -1. The injector and mass transfer line temperatures were set at 220 ° C and 280°C, respectively.

2.8 Statistical Analysis

The results obtained from the various experiments on the fermentation and granulation of grated cassava and attiéké are the average of three (3) replicates. The results of the analyses were subjected to an analysis of variance (ANOVA) at a significance level of 0.05 using JMP Pro 17 software. The Turkey test was used to determine significant differences between samples. A principal component analysis (PCA) was also performed to discriminate between the different samples.

3. Results

3.1 Microbiological and Physicochemical Quality of of Cassava Paste

3.1.1 Variation in the Microbial Load of Cassava Paste

Figure 1 shows the variation in the microbial loads and pH in the different fermented pastes. The results obtained showed a significant variation (P< 0.001) in microbial loads and pH during fermentation. This variation was marked by a significant increase (P< 0.001) in lactic acid bacteria and a reduction in pH in all fermented pastes. Unlike the variation in lactic bacteria and pH, the yeast, mould and Bacillus loads vary differently from one concentration of ferment to another. In the case of yeasts and moulds, when the dough is fermented with 8% inoculum, the microbial load increases, while those with 10 and 12% inoculum decrease over the 24 hours of fermentation. With Bacillus, when the dough is fermented with 8% and 10% inoculum, the microbial load increases and then decreases, while with 12% inoculum the microbial load decreases before increasing.

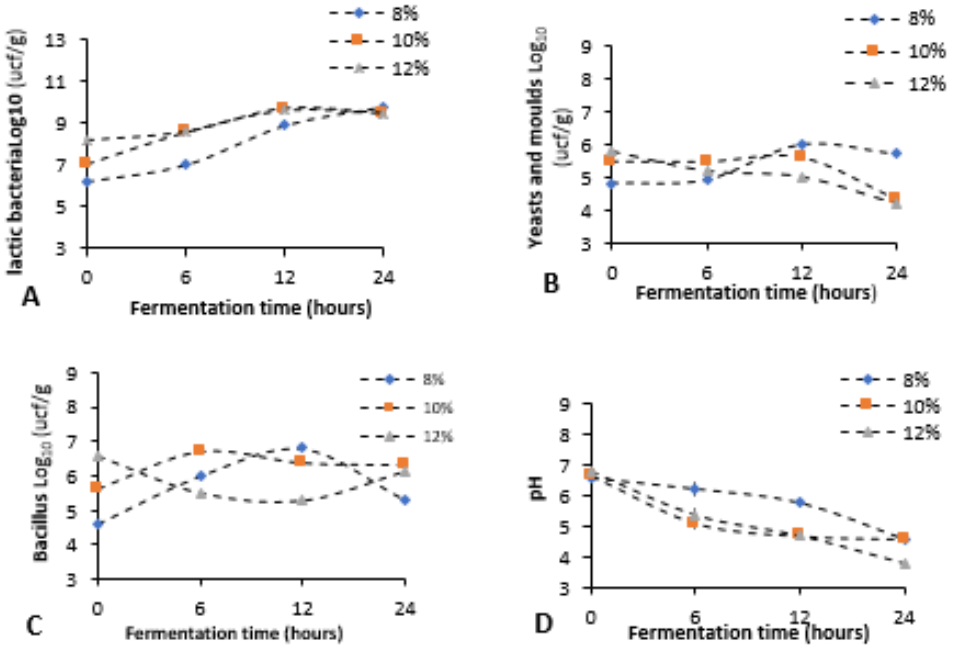

Figure 1. Growth kinetics of microorganisms and pH during fermentation according to ferment dose (A: lactic acid bacteria; B: yeasts and moulds C: Baccillus; D pH)

3.1.2 Variation in the Amount of Sugars of Cassava Paste

Table 1 shows the variation in sugars during fermentation. The results show a significant variation (P< 0.001) in sucrose, glucose, and fructose during fermentation. These sugars decreased significantly in all three different fermented doughs (8%, 10%, and 12%).

Table 1. Variation in sugars during fermentation

Sugars	Quantity of ferments (%)	Fermentation time (hours)			
		0	6	12	24
Sucrose (g/L)	8	22,75 ± 2,26^{a}	23,05 ± 2,45^{a}	6,8 ± 0,58^{b}	4,75 ± 0,32^{b}
	10	23,05 ± 1,88^{a}	23,45 ± 2,56^{a}	7,45 ± 0,32^{b}	4,75 ± 0,10^{b}
	12	24,4 ± 2,46^{a}	20,45 ± 2,00^{a}	8,50 ± 0,20^{b}	5,80 ± 0,22^{b}
Glucose (g/L)	8	11,00 ± 2,00^{a}	12,1 ± 1,22^{a}	7,60 ± 0,30^{b}	8,25 ± 0,54^{b}
	10	17,9 ± 1,88^{a}	17,8 ± 1,64^{a}	14,4 ± 1,23^{b}	13,15 ± 1,12^{b}
	12	19,15 ± 2,12^{a}	16,35 ± 2,01^{a}	12,25 ± 1,98^{b}	14,6 ± 1,88^{b}
Fructose (g/L)	8	7,35 ± 0,86^{a}	8,45 ± 0,47^{a}	0	0
	10	9,60 ± 0,56^{a}	10,3 ± 0,28^{a}	0	0
	12	9,15 ± 0,32^{a}	5,85 ± 0,12^{b}	0	0

Values in the same line with the same letter are not significantly different from each other according to Tukey's multiple comparison test at the 5% threshold. Values are expressed as Mean ± Standard Deviation (n = 3 trials).

3.1.3 Variation in the Amount of Organic Acids and Ethanol

Table 2 shows the variation in lactic acid, acetic acid and ethanol during fermentation. The results obtained showed a significant variation (P< 0.001) in these organic acids and ethanol during fermentation. These biochemical parameters increased significantly (P< 0.001) in the three different fermented pastes (8%,10% and 12%).

Table 2. Variation in organic acids and ethanol during fermentation

organic acids	Quantity of ferments (%)	Fermentation time (hours)			
		0	6	12	24
Lactic acid (g/L)	8	0	0,6 ± 0,01^{b}	6,5 ± 0,88^{a}	8,50 ± 0,47^{a}
	10	0	0	5,00 ± 0,56^{a}	7,95 ± 0,98^{a}
	12	0	0,7 ± 0,01^{b}	6,05 ± 0,24^{a}	9,60 ± 0,36^{a}
Acetic acid (g/L)	8	0,65 ± 0,01^{b}	0,20± 0,01^{b}	2,30 ± 0,06^{a}	2,80 ± 0,01^{a}
	10	0,60 ± 0,01^{b}	0,20 ± 0,01^{b}	1,95 ± 0,01^{a}	3,70 ± 0,04^{a}
	12	0,85 ± 0,01^{b}	0,10 ± 0,01^{b}	2,05 ± 0,01^{a}	3,35 ± 0,03^{a}
Ethanol (g/L)	8	0,35 ± 0,01^{b}	0,40 ± 0,01^{b}	0,50 ± 0,01^{b}	1,05 ± 0,01^{a}
	10	0,65 ± 0,01^{b}	0,75 ± 0,01^{b}	1,05 ± 0,02^{a}	1,15 ± 0,02^{a}
	12	0,65 ± 0,01^{b}	0,50 ± 0,01^{b}	0,65 ± 0,01^{a}	1,00 ± 0,01^{a}

Values in the same line with the same letter are not significantly different from each other according to Tukey's multiple comparison test at the 5% threshold. Values are expressed as Mean ± Standard Deviation (n = 3 trials).

3.1.4 Discrimination between the Different Cassava Pastes Produced

The biochemical variability of fermented cassava paste was described using principal component analysis (PCA). The analysis of the principal components carried out with all the biochemical and microbiological variables allowed the fermented pulps to be distributed and placed according to their potential in the plane formed by the F1 and F2 axes, as shown in Figure 2. The main axes, F1 and F2, contributed 83.80% of the total variability, with individual contributions of 57.50% for the Fl axis and 15.60% for the F2 axis. The representation of the fermented pasta in the plane formed by the FI and F2 axes allowed us to distinguish two large groups, the first consisting of pasta fermented between 0 and 6 hours and the second of pasta fermented between 12 and 24 hours. The first group is strongly correlated with high levels of lactic bacteria and high concentrations of lactic acid, acetic acid and ethanol, unlike the second group, which is correlated with high sugar concentrations and high levels of yeast and mould.

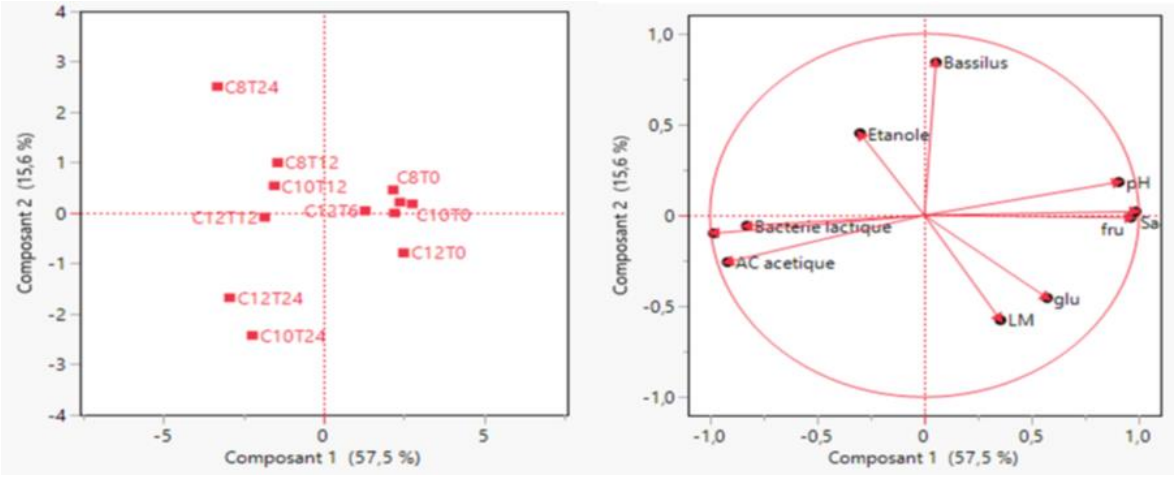

Figure 2. Principal component analysis of the biochemical variables of ‘attiékés’ in the plane

C8T0: cassava paste with 8% ferment without fermentation, C10T0: cassava paste with 8% ferment without fermentation, C12T0: cassava paste with 8% ferment without fermentation, C8T6: cassava paste fermented with 8% ferment for 6 hours, C10T6: cassava paste fermented with 10% ferment for 6 hours, C12T24: cassava paste fermented with 12% ferment for 6 hours, C8T12: cassava paste fermented at 8% ferment for 12 hours, C10T12:

cassava paste fermented at 10% ferment for 12 hours, C12T12: cassava paste fermented at 12% ferment for 12 hours, C8T24: cassava paste fermented at 8% ferment for 24 hours, C10T24: cassava paste fermented at 10% ferment for 24 hours, C12T24: cassava paste fermented at 12% ferment for 24 hours.

3.2 Microbiological and Physicochemical Quality of the Attiékés Produced Compared to the Control attiéké

3.2.1 Microbiological Quality and pH of the Attiékés Produced

Figure 3 shows the bacterial, Bacillus, yeast and mould lactic acid loads as well as the pH of attiékés from different fermentations. The results show that there are significant differences (P< 0.001) only in lactic bacteria and Bacillus loads between the different samples. Compared to the control, the lactic acid bacteria of attiéké C8T12 and C10T12 was identical, but lower than that recorded in C12T12 and higher than that of attiéké C8T24, C10T24 and C12T24, whose loads were zero. For Bacillus, the C10T12 and C12T12 attiéké were identical to the control.

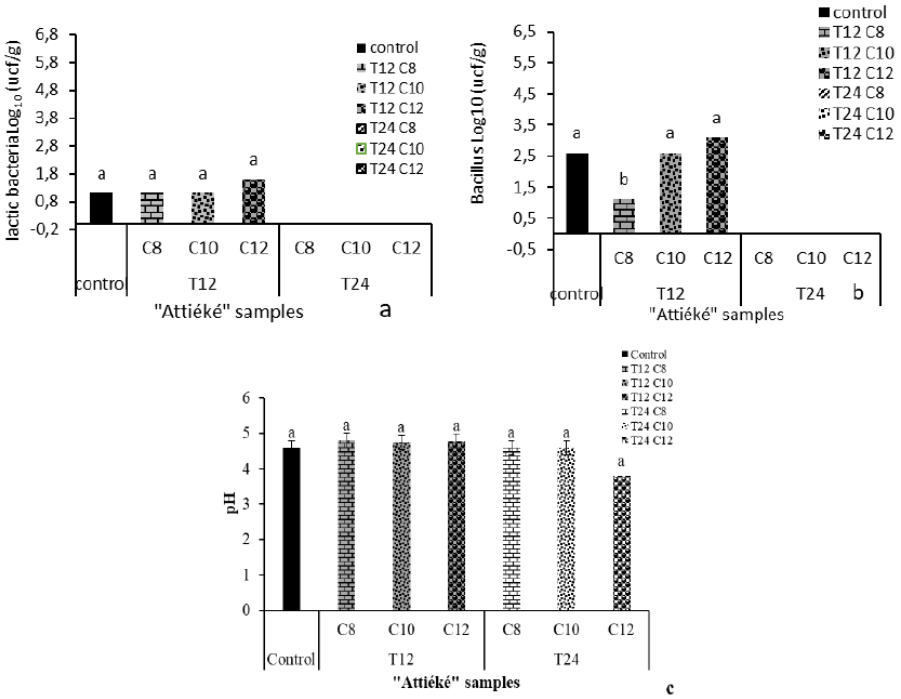

Figure 3. Load of microorganisms and pH of “attiéké” according to doses of ferments (A: lactic bacteria; B: *Bacillus*; C: pH). The letter a, b or c represents the level of significance; histograms with the same letters are not significantly different at p < 0.0. C8T12 : “attiéké” prepared from cassava paste fermented at 8% ferment for 12 hours, C10T12: “attiéké” prepared from cassava paste fermented at 10% ferment for 12 hours, C12T12: “attiéké” prepared from cassava paste fermented at 12% ferment for 12 hours, C8T24: “attiéké” prepared from cassava paste fermented with 8% ferment for 24 hours, C10T24: “attiéké” prepared from cassava paste fermented with 10% ferment for 24 hours, C12T24: “attiéké” prepared from cassava paste fermented with 12% ferment for 24 hours

3.2.2 Sugar Concentration in Attiékés Produced

Figure 4 shows the sucrose, glucose and fructose concentrations of “attiékés” from different fermentations. The results show that there are significant differences (P< 0.001) only in the sucrose and glucose concentrations between the different samples. Compared to the control, the sucrose load of “attiéké” C8T12, C10T12 and C8T24 is identical, but lower than that recorded in C12T12, C10T24 and C12T24.

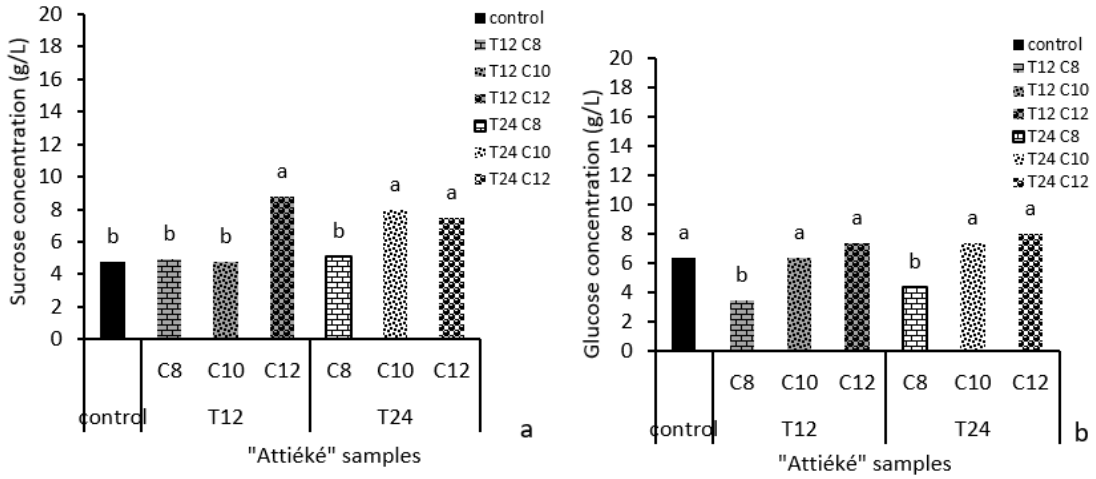

Figure 4. Quantity of sugars in “attiéké” according to the doses of ferments (A: sucrose; B: glucose). The letter a, b or c represents the level of significance; histograms with the same letters are not significantly different at p < 0.0. C8T12 : “attiéké” prepared from cassava paste fermented at 8% ferment for 12 hours, C10T12: “attiéké” prepared from cassava paste fermented at 10% ferment for 12 hours, C12T12: “attiéké” prepared from cassava paste fermented at 12% ferment for 12 hours, C8T24: “attiéké” prepared from cassava paste fermented with 8% ferment for 24 hours, C10T24: “attiéké” prepared from cassava paste fermented with 10% ferment for 24 hours, C12T24: “attiéké” prepared from cassava paste fermented with 12% ferment for 24 hours

3.2.3 Concentration of Organic Acids and Ethanol in the ‘attiéké’ Produced

The concentrations of lactic acid, acetic acid and ethanol in ‘attiéké’ produced by different fermentations compared with traditional “attiéké” from Dabou are shown in Figure 5. Of all the biochemical parameters investigated, only lactic and acetic acids recorded values. The results obtained showed that there was no difference ($P > 0.001$) in lactic and acetic acid concentrations between the different samples. Lactic acid concentrations ranged from 4 ± 0.34 g/L to 6.35 ± 0.56 g/L, while acetic acid concentrations ranged from 1 ± 0.01 g/L to 1.70 ± 0.01 g/L.

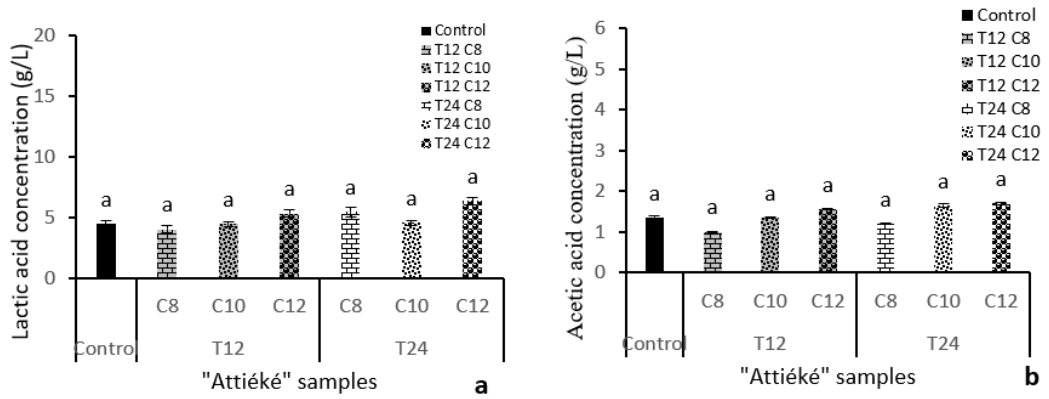

Figure 5. Quantity of organic acids and ethanol in “attiéké” according to ferment doses (A: lactic acid; B: acetic acid). The letter a, b or c represents the level of significance; histograms with the same letters are not significantly different at p < 0.0. C8T12 : “attiéké” prepared from cassava paste fermented at 8% ferment for 12 hours, C10T12: “attiéké” prepared from cassava paste fermented at 10% ferment for 12 hours, C12T12: “attiéké” prepared from cassava paste fermented at 12% ferment for 12 hours, C8T24: “attiéké” prepared from cassava paste fermented with 8% ferment for 24 hours, C10T24: “attiéké” prepared from cassava paste fermented with 10% ferment for 24 hours, C12T24: “attiéké” prepared from cassava paste fermented with 12% ferment for 24 hours

3.2.4 Discrimination between the Different ‘Attiéké’ Produced

The biochemical variability of the “attiéké” produced was described using principal component analysis (PCA).

The principal component analysis carried out with all the biochemical variables measured enabled the “attiéké” produced to be distributed and positioned according to their nutritional and and microbiological potential in the plane formed by the F1 and F2 axes, as shown in Figure 6. The main axes, F1 and F2, contributed 83.80% of the total variability, with individual contributions of 55.20% for the Fl axis and 28.60% for the F2 axis. The representation of the attiékés in the plane formed by the FI and F2 axes showed a strong correlation between the control attiéké and that prepared with the C10T12 fermant. These attiékés are characterised by low concentrations of sugar and organic acid and high levels of lactic acid and *Baccillus* bacteria.

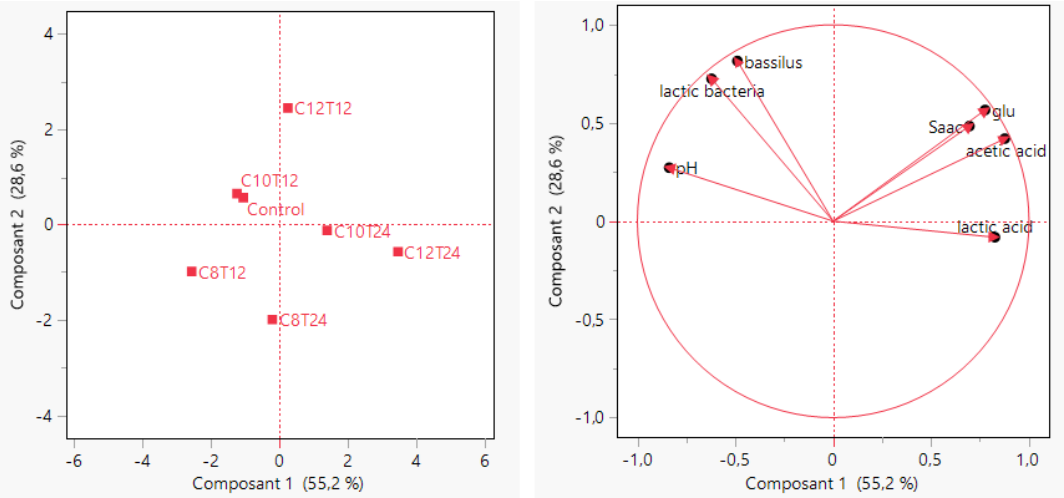

Figure 6. Principal component analysis of biochemical and microbiological variables of attiéké in the plan

C8T12: “attiéké” prepared from cassava paste fermented at 8% ferment for 12 hours, C10T12: “attiéké” prepared from cassava paste fermented at 10% ferment for 12 hours, C12T12: “attiéké” prepared from cassava paste fermented at 12% ferment for 12 hours, C8T24: “attiéké” prepared from cassava paste fermented with 8% ferment for 24 hours, C10T24: “attiéké” prepared from cassava paste fermented with 10% ferment for 24 hours, C12T24: “attiéké” prepared from cassava paste fermented with 12% ferment for 24 hours.

4. Discussion

For the production of “attiéké”, cassava ferment is added to the cassava paste to facilitate softening (Obilie et al., 2004; Assanvo et al., 2006; Charles, 2006) and to optimise the fermentation of the paste, as emphasised by Aboua (1995). This stage is essential to obtain the quality “attiéké”. The quantity of ferments (8%, 10% or 12%) used and the duration of fermentation (6, 12 and 24 hours) are closely linked to the biochemical and microbiological quality of the final product.

In fact, the load of lactic acid bacteria, *Bacillus*, yeasts, and moulds, as well as their fermentation products, varies according to the dose of ferment applied during fermentation of the dough. Variations in microbial loads observed during this fermentation are the result of the degradation of sugars and other carbon sources present in the cassava dough, which constitute ideal substrates for the growth of microorganisms (Tetchi et al., 2012). These microorganisms then produce waste products such as acids, CO_2, and alcohol, which contribute to the fermented flavour of the paste (Tetchi et al., 2012; Krabi et al., 2015). Djoulde et al. (2015) also observed a reduction in cassava paste sugars during fermentation. According to these authors, this reduction in sugar during fermentation is marked by an increase in acidity with the strong presence of lactic acid,, acetic acid and ethanol. There is also a similarity between the evolution of these physicochemical parameters in these two studies. Among the parameters studied, pH is an indicator of changes in the environment, while sugars, organic acids, and ethanol are products whose levels influence the environment.

The principal component analysis (PCA) of the different variables revealed that the 12 fermented pasta were grouped into two distinct blocks. The first block includes pasta fermented between 0 and 6 hours and pasta fermented between 12 and 24 hours. Pasta fermented between 0 and 6 hours is characterised by high acidity and a high sugar concentration, while pasta fermented between 12 and 24 hours has a significant concentration of lactic and acetic acids, as well as ethanol. Furthermore, the pasta fermented during this second period showed a high load of lactic bacteria. These results clearly indicate the influence of time on the fermentation process. Assanvo et al. (2017) observed biochemical differences between cassava pastes fermented for 6 and 15 hours. In

their study, the pH, titratable acidity and dry matter were respectively 5.10, 0.40, 38.83% in the pastes fermented for 6 hours and 4.54, 0.72, 38.98% in the cassava pastes fermented for 15 hours (Assanvo et al., 2017).

In this study, were selected pastes fermented for 12 to 24 hours for "attiéké" production and compared to the reference attiéké traditionally produced by processors. This choice was justified by the level of microbial and physicochemical parameters recorded in these pastes, which were very close to those in the literature recognised as ideal pastes for producing good "attiéké" (Djeni et al., 2011; Krabi et al., 2015; Assanvo et al., 2017). According to these authors, fermented pastes with pH between 4 and 5 are good for the production of quality 'attiéké'. The paste fermented for 12 to 24 hours had pH values between this reference.

Therefore, we went further in the search for the ideal concentration/fermentation time pair for the production of quality 'attiéké'. All doughs fermented for 12 to 24 hours were compared with a traditional quality 'attiéké'. The 'attiéké' with the profile closest to that of the control was made from dough fermented with 10% ferment for 12 hours. These two types of attiéké are characterised by high loads of *Bacillus* and lactic bacteria, compared to the other 'attiéké' samples. In addition, they have reduced levels of acidity, sugars, as well as lactic and acetic acids. This similarity between these two 'attiéké' makes it possible to determine the fermentation best pair between the concentration and the duration of fermentation for the production of "attiéké". Consequently, the optimal concentration of ferment is 10% with a fermentation time of 12 hours. Thus, this study provides even more precision on the quantity of ferments to use, because other studies had identified 12 to 15 as the ideal fermentation time (Djeni et al., 2011; Assanvo et al., 2017; Assanvo et al., 2019).

5. Conclusion

This study demonstrated that standardisation of fermentation parameters is essential to ensure the quality of "attiéké". An inoculum of 10% and a 12-hour fermentation of the cassava paste of the cassava paste are required to obtain an attiéké similar to that traditionally produced in Dabou. The attiéké resulting from this standardisation has a pH of 4.8. It has *Bacillus* loads of 2.6 log10 cfu/g, lactic bacteria loads of 1.1 log10 cfu/g, as well as a glucose concentration of 6.35 g/L, sucrose of 4.8 g / L, lactic acid 4.45 g/L and acetic acid 1.35 g/L. By integrating these standards, it is possible to add value to this traditional dish traditional dish, while at the same time meeting consumer expectations and strengthening the the attiéké industry in Côte d'Ivoire. Therefore, it is recommended that producers follow good fermentation practices.

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Authors contributions

This work was carried out in collaboration with all the authors. The author Dr. PMTA collected the samples, performed the and drafted the first version of the manuscript. Drs. ANV, YEK performed the statistical analysis. Dr. AC contributed to the protocol and manuscript. Drs. ANV, AC: participated in the correction of the manuscript. of the manuscript. Prof. NGA supervised, authorized the study analyses and participated in the participated in the correction of the manuscript. All authors read and approved the final manuscript.

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No additional data are available.

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