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Influence of Production Factors on the Physico-Chemical Characteristics of Fermented Cassava Dough and Sensory Evaluation of Attieke

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Abstract

Attieke is an Ivorian semolina which obtained by fermenting, pressing and steaming cassava dough. Attieke production remains a traditional activity carried out by less literate women. However, perceived differences in measurable factors and attieke qualities require an investigation of their influence on the characteristics of the pressed dough and attieke. The aim of this study is to improve the quality of the dough in relation to that of the attieke produced. The experiment was carried out on 4 production factors, namely the type of boiled or braised ferment, the incorporation rate of the ferment between 8 and 10%, the addition of oil from 0.1 to 1% and the fermentation time from 12 to 15 hours applied to the Improved African Cassava (IAC) variety. A complete experiment design of 16 samples of fermented dough and attieke was employed. These samples underwent physic-chemical analyses for the fermented dough and sensory evaluation for the attieke. It was found that, except for titratable acidity, reducing sugar content and ash content, the physico-chemical characteristics of the dough of IAC variety were significantly influenced by all production factors and their interaction. Fermentation time significantly influences 60% of the physico-chemical characteristics of the fermented dough. The type of ferment, the oil addition and the ferment rate have a significant influence at 40% of these characteristics. At the sensory level, color, acidity and grain binding with an explained variance of 34.60% were essential for the appreciation of the attieke samples. Thus, these production factors could be considered for the improvement of the fermented

dough and attieke production process.

Keywords

Influence, Production, Fermented Dough, Attieke

1. Introduction

The food consumption of African households is based on an undiversified diet characterized by a strong dominance of starchy foods. Cassava (*Manihot esculenta* Crantz) is one of these highly regarded energy sources after rice and maize [1]. This starchy tuber, which is less demanding in terms of climate and soil, gives more satisfactory yields than cereals. More than half of the cassava is produced in Africa in more than one hundred countries located in the tropics [2] [3]. African productions are generally intended for consumption, conservation and artisanal processing in short circuits. This is also the case for Côte d'Ivoire where cassava is one of the foodstuffs of interest in the national strategy for the development of food production and food security [4] [5] [6]. Most of this production is oriented towards the traditional processing of attieke, a cooked semolina dish originating in the southern lagoon zone [7] [8]. Attieke is produced from fermented cassava dough, which is initially a mixed grind of fresh cassava pods, a small number of pods fermented in two to three days, and oil. The dough is fermented for a few hours and then pressed in order to minimize the harmful effect of acidity and cyanide. The solid aspect obtained after fermentation and pressing is intended for the steps leading to granulation and cooking. Numerous small-scale attieke production units and its dough are multiplying in all regions motivated by the growing demand [9] [10] [11]. However, almost all of the attieke consumed and sold on the Ivorian market is produced in an artisanal manner with great variability in its organoleptic and hygienic quality [12] [13] [14]. This variability is due in part to the low control of parameters involved in the production process of fermented dough and attieke and a lack of theoretical and rational knowledge [13]. Fortunately, several studies have highlighted the microbiological [15] [16] [17] [18], biochemical and nutritional aspects [19] [20] [21] of attieke. However, little research has been done on the intermediate product, the fermented dough generally called placali [14] [22]. This by-product, which is in the second rank of research, should be considered as much as the attieke and the fermentation starters. Notable achievements on the biochemical and microbiological characterization of fermented cassava dough studied by [23] and on the effect of one or two production factors on attieke [15] [24] [25] are to be recorded. Faced with the significant demand for attieke on organized markets around the world, the Ivorian state through its national standardization body has approved standards on attieke [26]. However, the quality of the dough, which is less perceptible, is assessed according to the quality of the attieke produced by its suitability for granulation, which depends on its physical properties. Thus, the

adequacy of the production factors involved in the fermentation of the dough could contribute to the adoption of a relevant attieke process. The objective is therefore to identify the type of dough to produce an interesting sensory quality of attieke.

2. Materials and Methods

2.1. Vegetal Material

The plant material for this study was freshly harvested cassava. The study focused on the Improved African Cassava (IAC) variety harvested at 12 months on an experimental site of the Institute National Polytechnique Houphouët-Boigny of Yamoussoukro under the certification of an agricultural specialist. The harvest was carried out one day before the start of production, which took place in May during the rainy season.

2.2. Technical Equipment

The fermented dough and attieke were produced using a hammer mill, screw presses with stainless steel plates and a jack press to reinforce the pressing. Plastic utensils (basins, buckets and jute bags for fermentation, sieves, pots, trays) and metal utensils (stainless steel knives, charcoal hearths, electric hotplates for cooking) contributed to this production. Roberval and electronic precision scales and a cold room were used respectively for the different production weighing and the conservation of samples. The analysis equipment consisted of a precision balance (STARTORUIS), a pH meter (HANNA HI 8424) to determine the pH of the samples, a muffle furnace for the ash content, an oven (MEMMERT) to measure the dry matter, heating plates and a water bath. A spectrophotometer (VWR Collection) was used to determine the content of total and reducing sugars. Appropriate glassware and reagents were used.

3. Methods

Tubers were initially washed to reduce possible contamination and then underwent the traditional process of obtaining fermented dough and attieke. Four factors were applied, namely the type of ferment (boiled or braised), the ferment rate (8 to 10%), oil addition (0.1 to 1%) and the fermentation time (12 to 15 hours). The production of fermented dough and attieke was carried out according to 16 trials (Table 1).

Table 1. Experimental design matrix for dough cassava fermented and attieke productions.

n° Sample	Ferment (X1)	Ferment rate (X2)	Oil addition (X3)	Fermentation time (X4)	Sample code
E1	boiled	8%	0.10%	12 h	boT8H0, 1F12
E2	braised	8%	0.10%	12 h	brT8H0, 1F12
E3	boiled	10%	0.10%	12 h	boT10H0, 1F12
E4	braised	10%	0.10%	12 h	brT10H0, 1F12

Continued

E5	boiled	8%	1%	12 h	boT8H1F12
E6	braised	8%	1%	12 h	brT8H1F12
E7	boiled	10%	1%	12 h	boT10H1F12
E8	braised	10%	1%	12 h	brT10H1F12
E9	boiled	8%	0.10%	15 h	boT8H0, 1F15
E10	braised	8%	0.10%	15 h	brT8H0, 1F15
E11	boiled	10%	0.10%	15 h	boT10H0, 1F15
E12	braised	10%	0.10%	15 h	brT10H0, 1F15
E13	boiled	8%	1%	15 h	boT8H1F15
E14	braised	8%	1%	15 h	brT8H1F15
E15	boiled	10%	1%	15 h	boT10H1F15
E16	braised	10%	1%	15 h	brT10H1F15

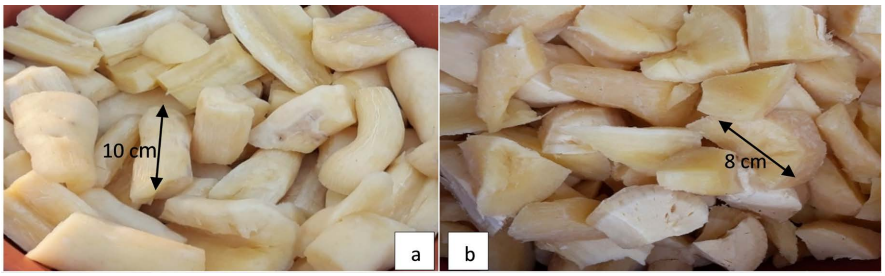

Figure 1. Boiled (a) and braised (b) tubers obtained by partial cooking.

Samples of 500 g of fermented dough and the resulting attieke were taken at each trial for physio-chemical and sensory analyses, respectively. These analyses included pH, acidity, dry matter, ash, fat, total sugars, reducing sugars, total carbohydrates, starch and protein.

3.1. Preparation of Boiled Ferment

The peeled tubers were placed in a pot containing boiling water at 100˚C elsius for a maximum of 15 minutes. The weight of tubers required for this preparation was 3.6 kg. At the end of this cooking time, the pieces were removed from the water, exposed in a bowl for cooling until they reached about 50˚C ± 5˚C (**Figure 1(a)**). Clean bags were used to pack them and the whole was conditioned in a bucket with a lid for 2 to 3 days, *i.e.* a duration of 52 hours. At the end of the anaerobic fermentation, they were removed from the bags and cleaned by scraping off the soft parts [27] to be ground.

3.2. Preparation of Braised Ferment

For the preparation of braised ferment, selected tubers of about 1 kg whose overall mass of 5 kg were put on a medium fire for their partial cooking for 15 minutes.

The cassava in contact with the embers is often turned over to make the operation homogeneous. They were removed from the fire afterwards and subjected to cooling close to 50˚C ± 5˚C. Afterwards, the tubers were peeled and the cut pulp (**Figure 1(b)**) was packed in two polypropylene bags to follow the same process as that of the boiled ferment.

3.3. Production of Dough

Tubers in good condition were selected and weighed before and after peeling. The tubers were then washed twice with potable water to avoid contamination of the skin on the pulp. The next step, grinding, consisted of grinding the pulp and the ferments separately. Once done, the grinds went to one of the important steps, which is the distribution of the pulp and the mixing with the ferment and oil according to the experimental matrix. After 12 and 15 hours of fermentation, the wet pulps underwent a pressing with the aim of obtaining a compact block that represents at least 62% of the initial pulp (**Figure 2**). At this point, the weights of the samples were taken and then 500 g was taken for biochemical analysis. The rest was sent to the sieving and granulation operations, pre-drying in the shade and cooking.

3.4. Production of Attieke

Production of attieke is the last phase of the process. It consisted of steaming 1 kg of granules over a period of 15 minutes, turning the sides to ensure even

Figure 2. Sample of pressed dough after fermentation (c) and granulation (d).

Figure 3. Sample of attieke packaged in airtight bag.

cooking. The samples of attieke removed from the fire and were put in a clean bowl. It was necessary to dislocate aggregates of grains with the spatula. This also helps to remove the initial hot vapors. Samples were taken and packed in airtight bags and transported to a cold room. Samples of 500 g of fermented dough and the resulting attieke were taken at each trial for biochemical and sensory analysis respectively (**Figure 3**).

3.5. Analysis of Biochemical Parameters

Determination of pH

The determination of pH by potentiometric method is carried out thanks to a pH meter. Ten grams of dough were taken, suspended in an Erlenmeyer containing 100 ml of distilled water heated to 60˚C contained then homogenized. The filtrate collected was detected with the pH meter (Hanna Brand) calibrated at the measurement temperature by two buffer solutions (pH = 4, pH = 10).

Titratable acidity

Acidity was evaluated according to the [28] method described by [13]. A 10 g mass P of finely ground product sample was diluted in 75 ml of distilled water, then macerated and the supernatant was filtered. 10 ml of filtrate V1 of the supernatant to which three drops of phenolphthalein are added is titrated under stirring, with a NaOH solution of normality (N2) equal to 0.1 N. This titrating base with a persistent pale pink color determines the volume V2 of NaOH poured. The normality N1 of the sampled supernatant is obtained by the following formula:

$$N1 = N2 \times V2/V1$$

The acidity in mEq/100g of material is expressed as follows:

$$mEq/100\ g = N1 \times 105/P$$

Dry matter

The dry matter is indicated by the [28] method determined on a sample of mass 5 mg (P) of pulp. The sample was placed in a capsule of mass M1 and kept in an oven at a temperature of 105˚C for 24 hours until a mass M2 was obtained. The dry matter content was determined by the following formula: $MS = 100 \times (M2 - M1)/P$.

Ash rate

The method used for the determination of ash content is that of [28]. It consists of taking, as a test sample, five grams of each dough (P0) in a clean and dry porcelain empty weight crucible (P1) of known mass. The whole crucible was heated in a muffle furnace at 550˚C for 6 hours. The crucible cooled in the desiccator is finally weighed with its incinerated content (P2). The ash content (C) is determined, in g per 100 g of fresh material according to the formula:

$$\text{Ash rate} = 100 \times (P2 - P1)/P0$$

Determination of fat

Fat was extracted by the cold method [29]. This method consists of allowing 5

g of dough (P0) to macerate for 3 h in a 100 ml solution of hexane. At the end of the extraction, the solvent is removed by evaporationin an oven at 105˚C for 30 minutes and then the residue and the flask (P1) are weighed together (P2). The fat content (MG), expressed in g/100g, is obtained by the calculation:

$$MG = 100 \times (P2 - P1)/ P0$$

Protein determination

Protein content is determined by the Kjeldahl method described by [29], which requires evaluation of total nitrogen. A mass of 300 mg of sample cassava dough dried in an oven at 70˚C for 18 hours is introduced into a tube, and then a 5 g catalyst tablet is added successively. The content of this tube is then mineralized through a digester after one hour. The mineralization obtained by clear coloration for which 4 ml of distilled water then 40 ml after cooling is introduced into a flask.

The next step is the distillation, which allows the displacement of ammonia whose presence is marked by the passage of the purple color to green due to the titration with NaOH to 0.1 N. The total nitrogen content determined is affected by the conversion coefficient 6.25 to evaluate the protein content.

Determination of reducing sugars

The quantification of reducing sugars was carried out according to the [30] Bernfeld method, whose principle is based on the reducing properties of sugars. In a 200 ml flask, 5 g of weighed doughs are introduced and then 50 ml of distilled water is added. After 60˚C, the whole is shaken and left to cool. The cooled solution is filtered and the filtrate is collected in a 100 ml flask. The first flask is rinsed with distilled water and the filtrate is brought to the gauge line. The determination of reducing sugars is done by reading the OD at 546 nm after heating in a water bath with 3.5 DNS.

Determination of total sugars

A 10 g sample of finely ground dough is introduced into a 250 ml flask. 200 ml of warm distilled water is added, homogenized and 15 ml of concentrated hydrochloric acid introduced. The whole is boiled for 3 hours. After that, the solution is allowed to cool and then neutralized with 6 N sodium hydroxide in the presence of phenolphthalein. The solution is then filtered over a 1000 ml flask. The residue is then washed with distilled water to the mark. For the determination of total sugars, the OD is read at 546 nm.

Determination of total carbohydrates

4 g of dough to which 40 ml of distilled water, 1 ml of zinc acetate 70% and 10 ml of 12 N hydrochloric acid are successively added, boiled for 2 hours 30 minutes, and cooled in a water bath. A few drops of phenolphthalein are added to the mixture which is neutralized with a 6N caustic soda solution. The obtained solution is cooled and filtered on Buchner. The brick-red precipitate obtained is dissolved with ferric solution and assayed with 5 pm potassium permanganate. The total carbohydrate content is given by the expression:

$$\text{Total carbohydrate} = [\text{Volume of permanganate} \times 10.047 \times 103/(20 \times 4 \times 103)] \times 100$$

Determination of starch content

The starch content was determined by calculation according to the formula of [31], which indicates a relationship between the starch and the content of total carbohydrates and total sugars.

Starch content = 0.9 × (Total carbohydrate content − Total sugar content)

3.6. Sensory Analysis

The sensory analysis consisted of describing and evaluating the sensory parameters of the attieke samples based on the sensory criteria of acidity, color, aroma, taste, grain binding, grain consistency, fiber content and grain size of the attieke. This descriptive test was carried out according to a sensory form with a scale going from 0 to 5. As a training, the jury was trained on the principle of the test and on the evaluation of the different sensory descriptors. During the analysis, each panelist evaluated, according to his or her perception, the sensory criteria of the samples taken in a random order. This analysis was carried out on a panel of 25 people.

3.7. Data Analysis

The results of the characterization of the doughs obtained in triplicate and the sensory evaluation of the attieke were recorded and processed using Excel and Satistica 7.0 software. The latter software was used to analyze the data through the significant differences observed between the means whenever the p-value was less than 5%. Radar graphes by given sensory descriptor, a Principal Component Analysis (PCA), a Kruskal Wallis ANOVA test, for significant differences between samples on a sensory descriptor were exploited.

4. Results and Discussion

The results of the physic-chemical analyses of the fermented cassava dough are presented in Table 2. The dry matter of the samples ranged from 46.361 to 57.66% and the ash content from 0.5 to 1.1. The pH of the doughs ranged from 4.09 to 4.35 with titratable acidities of 2.812 ± 0.834 mEq. The fermented pressed doughs had starch contents of 45.186 ± 2.628% and total carbohydrates of 51.136 ± 2.994%. Their total and reducing sugars are estimated at 0.93 ± 0.821% and 0.207 ± 0.049%, respectively. The majority of the protein and fat matter remain slightly below 1%.

4.1. Effect of Production Factors

The calculation of the coefficients required the use of the multiple linear regression method. Table 3 shows the significant coefficients of the physico-chemical characteristics in relation to the production factors at 5% risk. An overall observation of the table shows that the production parameters have a significant effect on the physico-chemical characteristics of the fermented cassava dough except for titratable acidity, reducing sugar content and total ash content, whose coefficients in absolute value remain below 2Se.

Table 2. Results of the physico-chemical analyses of the fermented cassava dough.

Samples	Dry M. (%)	pH	T.A. (mEq)	Fat M. (%)	R.S. (%)	T.S. (%)	Protein (%)	Ash (%)	TC (%)	Starch (%)
1	55.54	4.33	2	0.286	0.25	0.37	0.0003	0.7	54.45	48.67
2	51	4.35	2	0.152	0.21	1.98	0.0003	0.5	50.1	43.31
3	54.88	4.32	2	0.25	0.17	2.51	0.0007	1.1	53.38	45.78
4	49.6	4.33	4	0.567	0.21	0.26	0.0003	0.8	48.4	43.33
5	49.45	4.27	2	0.884	0.25	0.62	0.0003	0.9	47.55	42.24
6	54.45	4.28	2	0.878	0.17	0.26	0.0007	0.8	52.65	47.15
7	51.6	4.29	3	0.667	0.25	0.35	0.0005	0.8	49.8	44.51
8	52.05	4.25	3	0.443	0.21	2	0.0003	1	50.05	43.25
9	49.45	4.29	3	0.436	0.21	0.42	0.0003	0.8	48.25	43.05
10	53.06	4.27	4	0.585	0.21	0.37	0.0003	0.8	51.86	46.35
11	55.32	4.24	3	0.54	0.17	1.28	0.0004	1	53.93	47.38
12	52.7	4.29	2	0.663	0.13	0.77	0.0003	0.8	51.5	45.66
13	55.2	4.26	2	0.29	0.29	2.42	0.0004	0.8	53.4	45.88
14	54.34	4.26	3	0.189	0.17	0.33	0.0004	0.6	52.74	47.17
15	46.36	4.25	4	0.599	0.13	0.41	0.0004	1	44.36	39.56
16	57.66	4.09	4	1.352	0.29	0.53	0.0003	0.9	55.76	49.7
Mean	52.666	4.273	2.812	0.549	0.207	0.93	0.0004	0.831	51.136	45.186
Std. Dev.	2.965	0.059	0.834	0.309	0.049	0.821	0.0001	0.154	2.994	2.628
C.V. (%)	5.629	1.372	29.658	56.284	23.838	88.321	14.675	18.491	5.855	5.816

Note: Dry M.: Dry Matter; pH: Hydrogen Potential; TA: Total Acidity; Fat M.: Fat Matter; RS: Reducing Sugars; TS: Total Sugars; TC: Total Carbohydrates.

Table 3. Coefficients of physico-chemical characteristics.

Factors	MS	pH	A.T	MG	S. R.	S.T	Protéines	Cendres	G. T.	Starch
(Constante)	**52,668**	**4.275**	**0.562**	**0.541**	**0.208**	**0.934**	**0.0004**	**0.829**	**51.159**	**45.203**
Type of ferment (X1)	**0.442**	−0.006	0.037	0.047	−0.009	**−0.114**	−2.19E−05	−0.057	**0.52**	**0.57**
Ferment rate (X2)	−0.031	**−0.031**	0.013	0.079	0.014	**−0.069**	2.19E−05	0.02	**−0.371**	**−0.272**
Oil addition (X3)	−0.143	**−0.014**	0.062	**0.122**	−0.014	**0.088**	8.90E−06	0.093	−0.216	**−0.274**
Fermentation time (X4)	**0.343**	**−0.031**	0.063	0.041	−0.007	**−0.117**	**−3.97E−05**	0.008	**0.316**	**0.39**
X1X2	0.042	−0.007	−0.013	0.059	0.023	−0.002	**−7.33E−05**	0.005	0.057	0.053
X1X3	**1.543**	**−0.018**	−0.012	0.006	−0.002	0.029	**4.25E−05**	0.032	**1.491**	**1.316**
X1X4	**0.986**	−0.01	−0.012	0.068	0.009	**−0.203**	1.37E−06	−0.005	**0.97**	**1.056**
X2X3	**−0.578**	−0.01	0.063	0.024	0.014	**−0.131**	**−5.00E−05**	−0.017	**−0.581**	**−0.404**
X2X4	0.142	**−0.013**	−0.037	**0.128**	−0.008	**−0.156**	−8.90E−06	−0.005	0.127	**0.255**
X3X4	**0.408**	0.003	0.012	**−0.096**	0.007	**0.176**	−1.37E−06	−0.032	**0.46**	**0.256**
X1X2X3	**0.91**	**−0.019**	−0.012	0.021	0.019	**0.53**	−8.90E−06	0.045	**0.845**	**0.283**

Continued

X1X2X4	**0.698**	−0.004	−0.062	0.045	0.009	**0.221**	**5.27E−05**	−0.017	**0.695**	**0.427**
X1X3X4	**−0.362**	−0.006	0.037	0.042	0.012	**−0.203**	**−4.25E−05**	−0.045	**−0.297**	−0.084
X2X3X4	**−0.801**	−0.009	0.062	**0.137**	−0.004	**−0.253**	2.95E−05	0.055	**−0.836**	**−0.525**
X1X2X3X4	**1.39**	−0.01	0.036	**0.089**	0.023	**−0.197**	8.90E−06	−0.007	**1.417**	**1.453**
2 × pure error (2Se)	0.19184	0.011547	0.08666	0.084	0.0243	0.03656	3.00E−05	0.102	0.23038	0.0868

Note: Significant values have been bolted.

The two parameters, total acidity and reducing sugar content, are degradation products whose content increases during fermentation but probably undergoes a reduction during pressing. An important pressing of the fermented pulp would be at the base of this result. This pressing exerted a force on the cells to remove hydrocyanic acid, lactic and acetic acid from the fermentation [32] [33]. The factors, ferment rate, oil addition and fermentation time negatively affect the PH. This influence indicates the weak acid character of the dough if the factors tend to rise. Thus, the real impact of these production factors is reduced by the pressing of the dough.

Total sugar and starch contents are all significantly influenced by all four production factors. The type of ferment, the fermentation rate and the fermentation time each influence the total carbohydrate contents. This explains the importance of these production factors in the fermentation of cassava, which is essentially composed of carbohydrates. This fermentation is believed to be due to the activity of lactic acid bacteria, Bacillus and yeast [18] [34] [35]. During fermentation enzymes such as α-amylase, β-glucosidase, pectin lyase and linamarase produced mostly by *Lactobacillus plantarum* are involved in the bioconversion of cassava [36] [37] [38]. Substrates are decomposed during fermentation yielding carbohydrate residues after resource depletion. The type of ferment and the time of fermentation acting significantly on dry matter attests to this fermentation principle. The interactions of these production factors significantly influence the dry matter, total sugars, proteins, total carbohydrates and starches of fermented pasta. The oil addition by its significant action on the fat matter translates the importance of oil on the dough for the granulation.

4.2. Preponderance of Factors

Figure 4 shows that among the main factors studied, the fermentation time (X4) has a preponderant action on the number of physic-chemical characteristics of the fermented dough, because it acts significantly on most of these physic-chemical characteristics at 60%. Then, come the type of ferment (X1), the oil addition (X3), and the ferment rate (X2) which act for 40% on the number of physico-chemical characteristics studied. The interactions of the production factors have a preponderance of 50%.

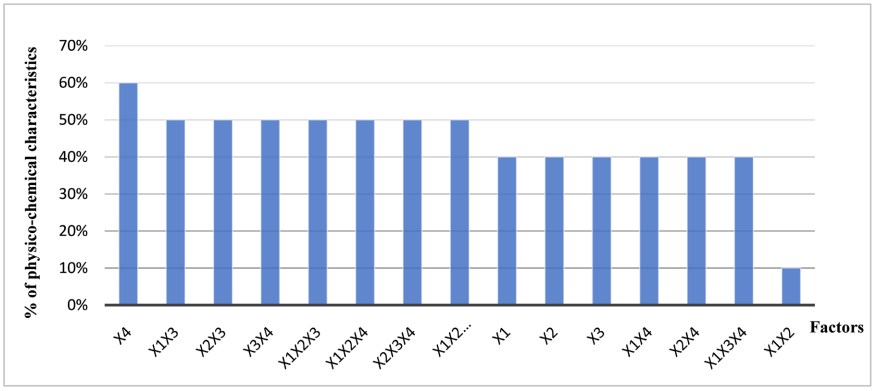

Figure 4. Proportion of physico-chemical characteristics influenced by the factors.

These results clearly show the importance of these 4 production parameters on the biochemical quality of the pulp. These production factors have a continuous effect after fermentation and pressing of the dough. Fermentation is the metabolic process conducive to the production of acids characterizing the pulp and attieke [15] [17] [18] [20] [25] [39].

The effect of fermentation time on the dough is similar to one presented by [33]. Indeed, cassava dough (IAC variety) fermented during its conservation was studied. The physico-chemical analysis of washed and unwashed pasta allowed to observe a reduction of cyanide content, pH value and an increase of lactic acid rate which stabilize from the 2nd week. The titratable acidity is mostly associated with the levels of lactic acid formed from fermentable sugars degraded by microorganisms. In general, fermentation requires appropriate proportions of ingredients and a duration. Thus, the inoculum of 6, 8, 10 and 12% and fermentation time in 6, 12 and 18 hours tested by [24] led to the gradual decrease on pH.

4.3. Sensory Description

The samples still did not show the same scores. Thus, the ANOVA Kruskal Wallis test relating to the comparison of the means of the scores of the samples for the sensory descriptors shows that the scores assigned by the panel differ significantly at the level of acidity ($p = 0.0399$), the binding between grains ($p = 0.0389$) and the size of grains (0.0459) through **Figure 5**. Indeed, at the level of these descriptors, the samples present a significant difference between them when p-value is less than 0.05.

The analysis of these plots seems to show a different aspect of sample means from one sensory descriptor to another.

The summary of Principal Component Analysis in **Table 4** shows that Component 1 has the largest explained variance (34.60%). It is correlated in order of importance to the descriptors overall grade, color, acidity, and binding between grains. This component is also correlated to samples E2, E10, E8, E6, E12, and E9 in order of importance of their coefficient. Component 2 is correlated with the descriptors flavor and grain size. These are associated with samples E11, E13,

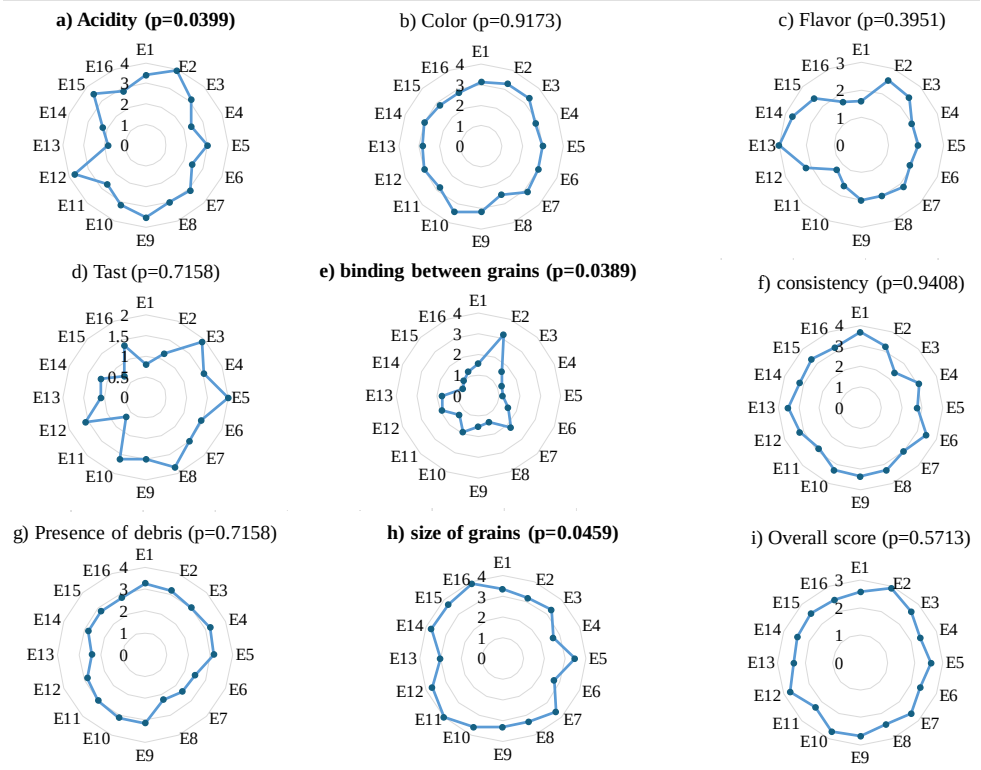

Figure 5. Radar plots and p-value of the Kruskal Wallis test of the samples at the level of sensory descriptors (in bold significative descriptors with p-value <0.05).

Table 4. Summary of Principal Component Analysis of the different sensory characteristics of the attieke.

Component with variables (sensory characteristics)	Coefficients	Explained variances (%)	Component with samples of the attieke
Component 1: Overall score Color Acidity Binding between grains	0.94 0.822 0.813 0.713	34.60%	**Component 1:** E2, E10, E8, E6, E12, E9
Component 2: Flavor Grain size	0.736 0.720	18.5%	**Component 2 :** E11, E13, E16, E14
Component 3: Grain consistance Taste	0.875 0.873	15.84%	**Component 3 :** E3, E5, E1, E15
Component 4: Presence of debris	0.623	10.73%	**Component 4:** E7, E4
Total		79.97%	

E16, and E14. Component 3 is also correlated to two descriptors, namely grain consistency and taste. These descriptors are associated with samples E3, E5, E1, and E15. Component 4 is represented by the only descriptor presence of fiber. It

is a characteristic of samples E7 and E4. The combination of production factors leads to samples of different ratings. Component 1 is made up of 6 samples more appreciated by the criteria of color, acidity and binding between grains. These criteria were consistently found by [25] after a sample collection in one locality. The binding between grains could be due to the improvement of the texture following fermentation which depends on its factors involved and the oil addition. The 6 samples of this first component have as their main production parameter: braised ferment (5/6), 8% ferment (4/6) and oil addition at 0.1% (4/6). Fermentation times are present in equal parts, but samples E9 and E6, with 15 hours of fermentation, do not respect the majority of the other three production parameters. According to the women producers surveyed by [40], the less ferment used, the stickier the attieke. This explains why Adjoukrou and Alladjan producers (7 to 8% ferment) use less ferment than Ebrié producers. In addition, the oil added in these communities is estimated to be about 0.1%, even less than that reported by [41]. Samples produced with the braised ferment retained more satisfaction showing the effect of this ferment on the organoleptic qualities of the attieke. With the braised cassava, a pleasant odor is noted. This braised ferment has the particularity of concentrating its moisture, sugars and minerals. The nutritive values of cassava are maintained inside the tubers without the addition of exogenous water. According to the producers surveyed by [13], the organoleptic characteristics of attieke obtained from the traditional braised ferment are respectively better than those obtained with the traditional boiled and raw ferments.

5. Conclusion

This study, which focused on dough samples produced from measurable production factors, showed the importance of these factors on the appreciation of attieke. Fermentation time before pressing is the most influential factor in the production of the dough. The satisfactory productions obtained presented different organoleptic characteristics remarkable by the binding of the grains, the color and the acidity and common production factors. For this study, the best conditions to obtain a good organoleptic quality of the attieke is to make a fermented dough with the braised ferment, 8% ferment, an addition of 0.1% of oil and a fermentation duration of 12 or 15 hours.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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