Journal of Food Research; Vol. 8, No. 6; 2019
ISSN 1927-0887 E-ISSN 1927-0895
Published by Canadian Center of Science and Education

Production Methods and Physicochemical Characteristics of Cassava Inoculum and Attiéké from Southern Côte d'Ivoire

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Received: August 22, 2019 Accepted: September 6, 2019 Online Published: September 18, 2019

doi:10.5539/jfr.v8n6p18 URL: https://doi.org/10.5539/jfr.v8n6p18

Abstract

Attiéké is a food from Côte d'Ivoire exported today in several countries. For evaluating production processes, determinant factors and quality attributes of attiéké, a production survey and a physicochemical study were carried out. The survey included 170 producers from the departments of Abidjan, Dabou and Jacqueville, major production areas. Traditional attiéké (Adjoukrou, Ebrié, Alladjan) and a commercial type Garba were investigated for physicochemical analyses. The cassava variety (98% of producers) had no effect on traditional cassava inoculum but had an impact on attiéké quality. The step of fermentation is necessary. The difference between studied attiéké related to microflora of inoculum whose identification may provide adequate explanations on the product. Respect for the various steps of manufacturing process is also essential. Physicochemicals confirmed observed differences between attiéké types. Organoleptic characteristics are criteria of differentiation between attiéké. The quality of preference is well-made grains without fibers. The results obtained also highlighted the risks faced by regular consumers of Garba due to its high cyanide content (12 mg/100g MS) compare to other attiéké (4.41 mg/100g MS).

Keywords: cassava, inoculum, production, attiéké, physicochemicals, organoleptic characteristics, Côte d'Ivoire

1. Introduction

Cassava, *Manihot esculanta* Crantz is one of the most important food crops in Côte d'Ivoire. With an estimated production of 4.54 million tonnes in 2016 (FAO, 2018), and a consumption of 100-110 kg / year per inhabitant living in urban areas, cassava plays a crucial role in food security of both rural and urban populations as well as job and incomes for the involved actors. According to FAO data, between 45 and 50% of Ivorian cassava production go to urban markets. Mainly consumed in the forms of placali (fermented dough) and attiéké (steamed semolina), cassava occupies a dominant place in culinary habits of Ivorians (Anonymous 1, 2016).

Several varieties of cassava exist and can be classified into three broad groups according to the root content in cyanogenic glucosides. These products are found in high doses in bitter varieties, justifying their transformation before consumption (Assanvo et al., 2017). Thus, toxic cassava varieties are used in manufacturing many fermented products, because of a better technological transformation aptitude. Among these traditional foods, attiéké remains the most consumed food (Assanvo, Agbo, Behi, Coulin, & Farah, 2006)

Cyanide detoxification occurs when plant tissue is disrupted and glycosides, known as lydene and lotaustraline, after disruption of the root cell structure, come into contact with B-glycosidases found in distinct intracellular compartments in intact tissue, being cleaved and producing glucose and α-hydroxynitriles. The latter, when catalyzed by hydrrixinitrile lyase, transforms into HCN and corresponding ketones in a process called cyanogenis (Cagnon, Cereda, & Pantarotto, 2002).

Originally, Attiéké was prepared and consumed exclusively in a restricted ethno-cultural setting in the Ivorian lagoon complex where the Adjoukrou, Ebrié, Alladjan, Avikam, Aizi and Neo ethnic groups live. Of these, Adjoukrou, Ebrié and Alladan remain the largest producers and consumers. However, the product has overflowed its original environment and is now consumed throughout the country and even beyond its borders because of its "ready-to-eat" presentation (Assanvo et al., 2006). The attiéké, semolina or couscous of steamed cassava is a food produced from fermented cassava paste.

The multiple manufacturing methods of attiéké vary according ethnic groups and are based on a principle of traditional and non-standardized fermentation. In addition, attiéké has shifted to market production, a result of ever-increasing demand in large urban centers (Diop, 1992). The lack of control of production factors (cassava inoculums, temperatures and time) by new producers justifies most of the constraints related to production, including manufacturing defects and low yield (Assanvo, 2008).

The aim of this study was to highlight manufacturing processes, insufficiencies in commercial activity, physicochemical quality of the various ingredients, risks incurred by consumers and quality attributes sought by traditional producers of attiéké.

2. Method

2.1 Sampling for Surveys

The study was conducted from June to December 1999 in the departments of Abidjan, Dabou and Jacqueville (Lagoon Region), areas of regular attiéké production (Figure 1).

A pre-survey was conducted in Adiopodoumé in April 1999 to collect information for completing the questionnaire. The village of Adiopodoumé is located at 17 km from Adjamé, on the outskirts of Yopougon where lives a large proportion of Ebrié. A complementary survey was carried out in 2006 and 2017 for an update of data.

The investigation focused on factors determining the quality of finished products. They were raw material, inoculum, stages of attiéké production, different products obtained and their organoleptic characteristics. The selling prices were also sought. The sampling method was 3 cluster sampling with, at the primary level, the departments surveyed, at the secondary level the villages (or production sites) and at the tertiary level the producers surveyed (Table 1). The chosen primary units (departments surveyed) corresponded to a production area of an attiéké type: Abidjan (type Ebrié in majority and type Garba), Dabou (Adjoukrou type exclusively) and Jacqueville (Alladjan type only).

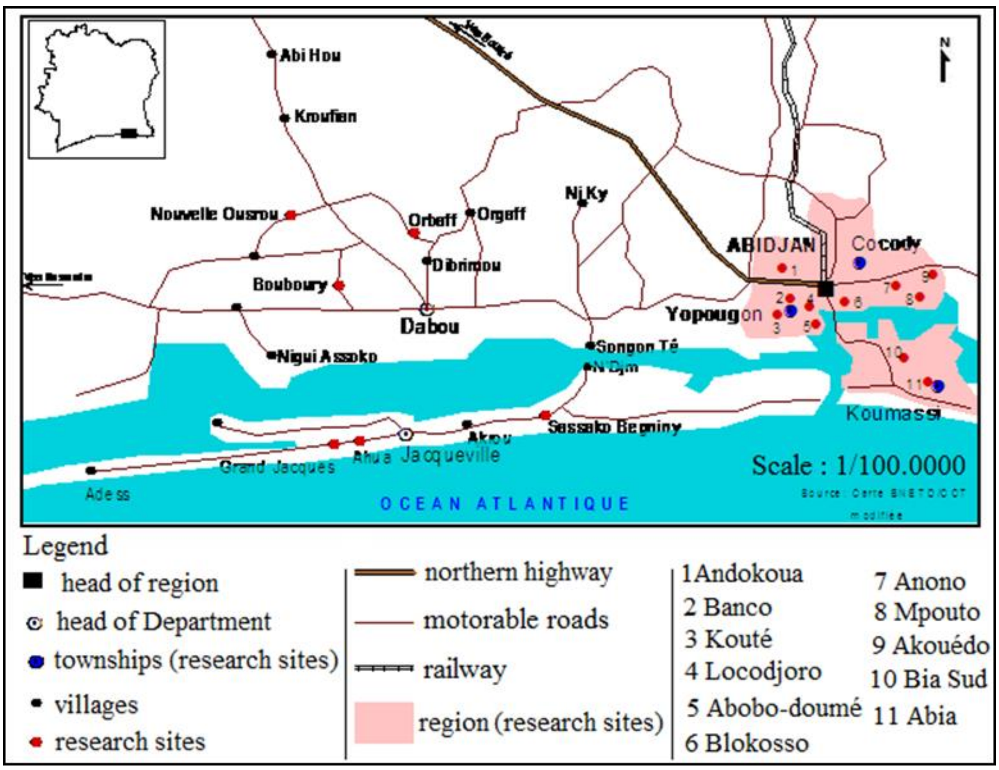

Figure 1. Map of study site presenting the attiéké production areas included in the survey

Scale: 1/1000.000; source: Map BNETD / CCT modified

Table 1. Sample size used for the attiéké production survey

Department of Lagoon region	Number of villages	Number of producers surveyed	Type of attiéké studied
Abidjan	11	110	Ebrié, Garba
Dabou	3	30	Adjoukrou
Jacqueville	3	30	Alladjan
Total	17	170	

In each department, 3 production villages were randomly selected. However in Abidjan zone, 11 villages were investigated. In each village, 10 producers randomly selected were interviewed. 170 traditional producers were interviewed in 17 production sites.

2.2 Sampling of Attiéké

Of 10 respondents in each village, three producers were randomly selected for collecting 100 g of attiéké. A total of 54 samples was collected, including 9 samples of each type of attiéké and Garba. At the laboratory, samples were dried and used automatically for determination of particle sizes. 54 other attiéké samples were used for physicochemical analyzes. For each producer, a total of 36 samples (9 inoculums/ethnic group/each attiéké) were also collected, directly transported and stored -18 °C at the laboratory for physicochemical analyzes.

2.3 Sampling for Calculation of Quantities Required for Attiéké Production

At each sampling and each stage of manufacturing process, weighings were performed for calculating the amount required. This was performed from 9 yield values of IAC (Improved African Cassava) variety transformation.

2.4 Physicochemical Analyzes

2.4.1 Determination of Particle Size

50 g of attiéké were lyophilized (freeze dryer Christ Alpha 1-2) and reduced (MFC grinder, IKA ® LABORTECH,) in flour and passed through an air draft sieve (Alpine AG 910) during a rotation of 10 minutes. The characteristic variable of separation was the diameter equivalent to that of the largest sphere passing geometrically through the meshes of the sieve considered (Melcion, 2000).

2.4.2 Determination of Dry Matter of Cassava Inoculums and Attiéké Studied

Ten (10) g of sample were weighed (AG 24 Delta Range scale) and oven dried (Memmert) at 103 ± 2 °C for 24 hours. Dry matter was determined at constant weight AOAC (1984). Experiments were repeated three times.

2.4.3 Determination of pH and Total Titratable Acidity

10 g of attiéké or inoculum were suspended in distilled water (90 ml) and homogenized. The pH was measured using a Calimatic 761 pH meter, Knick, the further solution, obtained after adding distilled water (100 ml) and 2% phenolphthalein (8 drops), was titrated with NaOH 0.1 M (Amoa-Awua, Appoh, & Jakobsen, 1996). The assays were repeated 3 times.

2.4.4 Enzymatic Determination of Acid Levels

The determination of lactic acid and acetic acid was carried out by the enzymatic method of Böhringer Mannheim (acetic acid kit No. 0148261, D-/L-lactic acid kit No. 1112821, R-Biopharm GmbH, D-64293 Darmstadt).

2.4.5 Determination of Starch

Briefly the suspension obtained from 100 mg of attiéké flour and 25 ml of ethanol 40% (in distilled water) was mixed using a magnetic stirrer for 20 minutes at room temperature and centrifuged (Mistral 4L centrifuge) for 5 minutes at 2000 g. The pellet in distilled water (25 ml) was boiled for 20 minutes in a water bath and hydrolysed by adding 1 ml of termamyl ® (Novo Nordisk Ferment). A control sample of standard starch was glucose.

The absorbance of the resulting NADPH was measured at 340 nm with spectrophotometer (WTW photolab S12). The amount of glucose released is stoichiometrically equal to the amount of NADPH formed. The tests were repeated 3 times.

2.4.6 Determination of Total and Reducing Sugars

Attiéké flour (1 g) was treated with ethanol (80% v/v) and defecated with lead acetate solutions (10% v/v) and oxalic acid (10% v/v) according to the method of Agbo, Uebrsax and Hosfield (1985). Each extract obtained (1 ml) was treated with phenol sulfuric (5% v/v) for total sugars (Dubois, Gilles, Hamilton, Rebers, & Smith, 1956), or DNS (3, 5 Dinitro-Salicylic acid) for reducing sugars (Bernfeld, 1951).

The absorbance of the various solutions was measured at λ = 490 nm for total sugars and λ = 540 nm for reducing sugars using a spectrophotometer (WTW photolab S12). Standards were glucose for total sugar and glucose/fructose for reducing sugars. Each sample was assayed in triplicate.

2.4.7 Determination of Cyanide

This assay was performed on 100 mg of attiéké flour using picrate method (Bradbury, Egan, & Bradbury, 1999). A kit (all reagents) has been produced: kit B2 (cassava semolina) and Absorbances (A) was measured at 510 nm with spectrophotometer (WTW photolab S12) following immersion of picrate paper in distilled water (5 ml) for 30 minutes.

A control (value = 0) and a standard (expected value = 50 ppm) were included. Total cyanide content (ppm) was calculated using the formula: Cyanide (ppm) = 396 A. The assays were performed in triplicate for each sample.

2.4.8 Protein Determination by the Kjeldahl Method

The protein assay was performed using Kjedahl method associated to a Buchi. The determination of protein was made on 1 g to 0.01 mg of attiéké fine powder. The mineralization was carried out using a Büchi 435 digester (Büchi Laboratoriums, Technik AG). The distillation and determination of nitrogen were carried out using a distillation unit Büchi 339 (Büchi Laboratoriums, Technik AG,). The protein content was obtained directly at this unit, using a conversion factor of 6.38. A triple determination was performed on each sample (Commission du Manuel Suisse des Denrées Alimentaires, 1994).

2.4.9 Determination of Percentage of Mineral Substances (ash)

3 g of attiéké flour was burned in a muffle furnace at 450 °C and incinerated until complete mineralization. The residue was determined by the gravimetric method (AOAC, 1990) in triplicate.

2.4.10 Determination of Fat

Fat determination was performed using Soxhlet method (AOAC, 1995). The fat contained in 8 g of attiéké flour was extracted with 180 ml of petroleum benzine or petroleum ether at 100 °C for 4 hours. After evaporation, fat amount weighed in triplicate.

2.4.11 Determination of Total Dietary Fiber (fat)

The total dietary fiber assay was performed using the modified enzymatic-gravimetric method (Commission du Manuel Suisse des Denrées Alimentaires, 1994).

2.4.12 Calculation of Digestible Carbohydrates

The percentage of digestible carbohydrates in samples was obtained by difference between dry matter and sum of protein (% P), fat (% MG), ash (% C) and fiber.

$$\%\ Digestible\ carbohydrate = MS - \Sigma\ (\%\ MF + \%\ P + \%\ C + F) \quad (1)$$

2.4.13 Calculation of Production Yield

At each stage of manufacturing process of each type of attiéké, the quantities of the various stages (from cassava to attiéké) were weighed. The final yield of the transformation (%) of cassava roots in attiéké was determined.

2.5 Statistic Analysis

The results of production surveys were recorded in a database and frequencies were calculated. The analysis were performed using SAS software (version 8.0) based on biochemical parameters. A one-way model of variance analysis was used. The factor is the type of attiéké.

The dependent variables (responses) considered were biochemical parameters. Using the Student-Newman-Keul multiple comparison tests with the relative risk assessed, a ranking of averages was performed.

The significant threshold is α = 0.05.

The results of particle size distribution were interpreted by applying the logarithmic form of the Rosin, Rammler and Sperling equation.

3. Results

3.1 Attiéké Production

3.1.1 Raw Materials

The main raw material of attiéké, is roots of sweet and bitter cassava depending on the regions of production. Previously, attiéké was produced from only bitter varieties or the mix. Today, mixture is predominant, bitter variety (IAC) becoming insufficient. Most producers (about 98%) state bitter varieties give a better quality attiéké. The cassava roots used were fresh (0-1 week) depending on cassava varieties.

3.1.2 Production Techniques of Attiéké

3.1.2.1 Principle of Manufacture and Desired Characteristics

According to producers surveyed (98%), cassava variety has an impact on attiéké quality, however other parameters such as fermentation, granulation, drying and steaming, remain decisive stages for obtaining a good attiéké.

3.1.2.2 Preparation of Cassava Inoculum

In the study area, two types of inoculum are used (Figure 2):

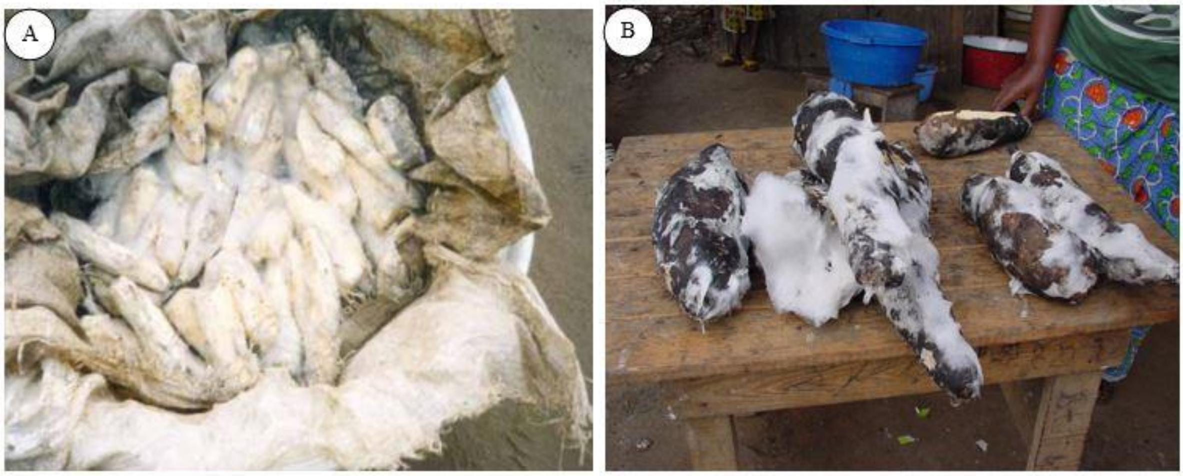

Figure 2. Two different types of inoculum obtained after 2-3 days of cassava root fermentation

A) Inoculm of peeled and boiled cassava root (Assanvo, 2008)

B) Inoculum based on unpeeled and braised cassava root (Assanvo, 2008)

The peeled and boiled cassava root inoculum is increasingly used.

The braised cassava root inoculum is endangered in all regions visited due to preparing constraints according to producers (82.35%).

The traditional inoculum called "Lidjrou" in Adjoukrou language, "Magnan" in Ebrié and "Bédé Fon" in Alladjan is obtained from a spontaneous fermentation. This inoculum is made from one or many varieties (sweet or bitter) of cassava. About 2-3 kg of fresh cassava roots were peeled, washed and boiled in water (100 °C ± 2) for 5-10 minutes. The cassava was cooled at room temperature (28-35 °C) and packaged in a bag or set of fillets already used for previous fermentations. The whole is put in a basket or cardboard and kept at room temperature (28-35 °C) for 1-3 days. For braised inoculum, non peeled cassava is cooked on embers.

Cassava variety does not matter much for obtaining a good inoculum. It should only be well fermented, very soft to the touch, yellowish (covered with mushrooms), releasing a pleasant smell when ready. 2-3 days post fermentation, cassava is cleaned and crushed. The inoculum still represents 5-10% of fresh cassava roots used for preparing attiéké and Garba.

3.1.2.3 Peeling and Washing

The fresh roots are peeled, crushed and washed several times for eliminating all visible impurities and preserving the color of finished product. For attiéké Garba, all these treatments are useless and one washing can be done.

3.1.2.4 Red Palm Oil

Oil is mixed with inoculum just before grinding. Its amount usually did not exceed two tablespoons: 0.1% for Adjoukrou and Alladjan and about 0.1-0.15% for Ebrié. For Garba, about 1-2% is added. Producers used discolored by heating or refined (rich in vitamins A and E) palm oil. 98% of producers state the small amount of added oil has an impact on the color of attiéké and prevents grains from stick.

3.1.2.5 Grinding of Crushed Cassava, Inoculum and Palm Oil

The mixture palm oil-inoculum is added to cleaned fresh cassava roots before grinding or to the resulting paste. The smaller the grinder's mesh (diameter = 1.5-2 mm), the more it gives a fine paste. For attiéké Garba, the sieve meshes are larger (diameter = 3 mm), leading to a coarser texture of the finished product.

3.1.2.6 Wetting with Water of the Dough

Water (about 10-20% of paste) is added to the dough for well homogenization. The quantity of water is greater for attiéké Ebrié (10-20%) than Adjoukrou and Alladjan types (7-10%). However, the dough should not be too liquid or compact.

3.1.2.7 Fermentation of Dough

The fermentation time (12-15 hours) of dough varies according producer who feels quality to the touch. All producers unanimously state the inoculum makes dough suitable for processing into grains. The fermentation technique does not differ according types of attiéké. For Attiéké Garba, the time and quality of fermentation were variable. This time ($\leq$ 6 hours) largely depends on the delivery time and quantity ordered.

3.1.2.8 Pressing of Fermented Dough

All the producers surveyed used a mechanical screw press for pressing fermented dough in a nylon bag to eliminate excess water and facilitate granulation. Producers knew the appropriate humidity rate checked to the touch. Depending on the daily amounts of cassava roots used, the pressing time was 1-3 hours. This stage was also dependent on cassava variety. To save time, some producers combined fermentation (about 2-8 hours post fermentation) and pressing. This process is widely used for attiéké Garba.

3.1.2.9 Sieving the Dough after Pressing

After pressing, the fermented flour is sieved successively through large meshes (4-5 mm) and small mesh (1.5-2 mm) for removing impurities, and obtaining semolina (crackling) or cleaning and fining flour ready for granulation.

3.1.2.10 Granulation of Flour

Grains were obtained using either a plastic bowl (510 liters) for Ebrié or a wooden bowl (Adjoukrou and Alladjan). Granulation occurs as a result of rotational movements and is stopped when grains are round, well-formed and solid (Figure 3). Producers can decide to favor a size: large, medium, small and fine grains.

The choice of grain size is related to the type of attiéké. Hand granulation does not exist in manufacturing process of Garba type.

3.1.2.11 The Drying of Uncooked Grains

Drying is used to hardening grains and reducing water amount for maintaining certain moisture in the finished product after cooking. Grains are sun dried on large plastic sheets (Ebrié) or raffia trays (Adjoukrou and Alladjan) for at least 1 hour depending on solar radiation. The quality of drying is appreciated by the naked eye. In rainy weather, grains are exposed in the kitchen at 30-40 °C due to fire.

Ebrié from Abidjan used various drying racks (table or stool) for hygiene measures. There is no drying stage for attiéké Garba, resulting in pasty and tacky characteristics.

3.1.2.12 The Winnowing of Uncooked Dried Grains

This step is made in raffia trays (Adjoukrous and Alladjans) or plastic bowls (Ebriés). It requires the wind, for eliminating fibers and small size grains. The winnowing step is not applied for attiéké Garba containing too fibers.

Figure 3. Uncooked semolina of cassava roots before drying (Assanvo, 2008)

3.1.2.14 The Cooking

Steaming is done using traditional couscous cooker about 20-30 minutes. The cooked grains are cohesive with a slightly translucent appearance (Figure 4).

A characteristic pleasant slightly fermented smell emerges. However, cooking with wood fire revealed a small aroma of charcoal. The color (cream, light yellow or beige or off-white, Figure 5) depended on cassava variety and oil (case of attiéké Garba).

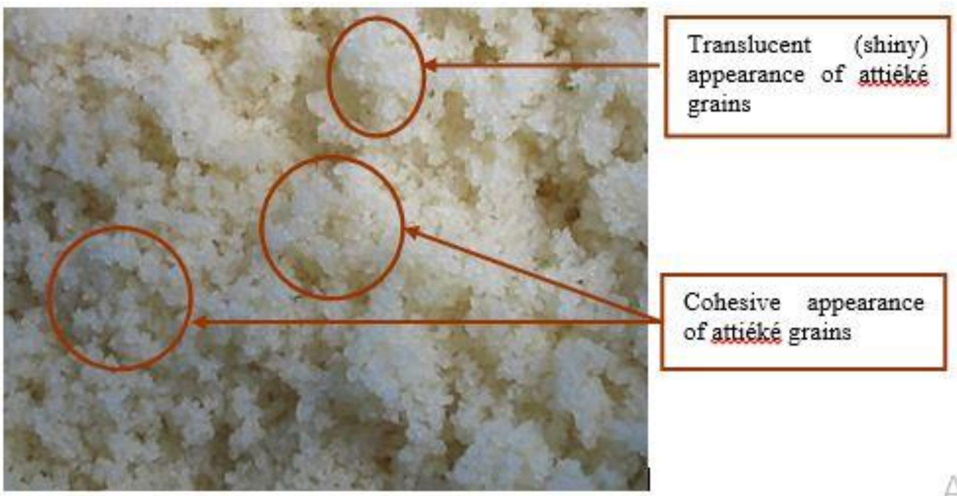

Figure 4. Translucent and cohesive aspects of attiéké (Assanvo, 2008)

Translucent (shiny) appearance of the grains

Cohesive appearance of attiéké grains

Figure 5. Colors of freshly prepared Ebrié attiéké (Assanvo, 2008)

a) Off-white color

b) Yellow-cream color

3.2 Characterization of Different Types of Attiéké

Each type of attiéké is linked to a process specific to each ethnic group. Thus, the Adjoukrou produce attiéké Adjoukrou, the Alladjan, attiéké Alladjan and the Ebrié, attiéké Ebrié. The Ebrié put more emphasis on production of attiéké Garba than the other ethnic groups. The manufacturing processes of studied attiéké are presented respectively in Figures 6a, 6b, 6c and 6d. Table 2 summarizes differences between the quality of traditional attiéké (Adjoukrou, Alladjan and Ebrié) and commercial attiéké Garba (Figure 7).

3.2.5 Quality Descriptors of Attiéké Types and their Importance

A list of quality descriptors of attiéké has been established among producers. The descriptors are ranked in order of importance of percentages as attributed by the 170 producers interviewed. These results revealed the importance of taste (94%), odor (64%), shelf life (56%) and color (40%), (Figure 8).

Color (40%) and translucent appearance (30%) also appear as descriptors that highly matter in the appreciation of producers as attributes rounded grains, well-formed grains (30%) and quantity of fibers (20%).

Table 2. Differences in assessment parameters of traditional attiéké (quality 1) and Garba (quality 2)

Rating parameters	Attiéké (quality 1)	Garba (quality 2)
Age of inoculum:	2-3 days	Indefinite, may vary depending on demand (1-4 days)
Quantity of inoculum in relation to the amount of fresh cassava roots	On average 7-10% depending on producing ethnic group (attiéké type)	On average 2-5% compensated by a large amount of oil
Quantity of discolored palm oil after heating	Small (0.1%)	Large (1-2%)
Grains	Well-formed	Poorly formed or absence
Grains drying	Mandatory	Eliminated
Presence of fibers (winnowing)	Very little	Much
Humidity	Normal (varying on average from 44-49% depending on the type of attiéké)	Abnormal (varying on average from 49-61% and can reach 80% sometimes)
Conservation	1 week at least	2-3 days
Consumption	Family and commercial	Only commercial
Cost	Expensive (1-2 fold more expensive than the Garba)	Cheaper
Quality (taste, appearance, odor)	Very good to good	Good to bad

Other descriptors (provides a well-being, stickiness, size, moisture, elasticity) were secondary for the 170 producers (Figure 8). Descriptors such as firmness, attiéké well-cooked and flavor had no importance.

3.2.6 Frequency of Production, Average Daily Quantities and Prices

The production of attiéké per week is done at frequency of 2-3 times depending on the ethnic group (Table 3). "Agbodjama" is prepared once or twice (few times) a week.

The average amount produced/day was around 30 kg for attiéké and 60 kg for Garba. However, this quantity may vary up or down depending on the amount and variety of cassava, or available labor. Attiéké Garba is cheaper than the other three types of attiéké. Commercial attiéké Ebrié is cheaper compared to Adjoukrou and Alladjan types. However, attiéké "Agbodjama" is the most expensive. Table 3 gives prices/kg by type of attiéké.

Attiéké Ebrié is most often packaged in plastic bags of 100 CFA F ball unlike the Adjoukrou and Alladjan types. The prices of balls of Attiéké Adjoukrou and Alladjan ranged from 150 CFA F to 250 CFA F. The smallest share of attiéké Garba sold for immediate consumption at the retailer costs 50 CFA F. This rate does not exist for the usual attiéké.

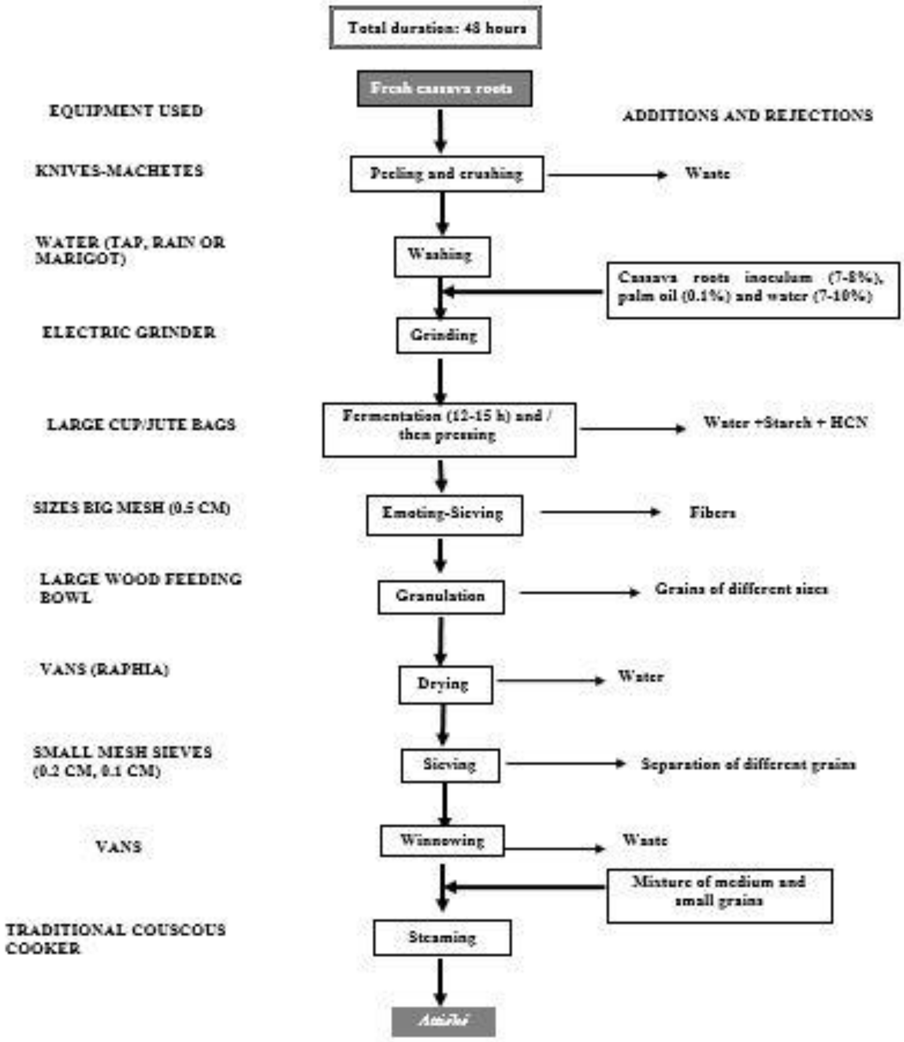

Figure 6 (a). Diagram of the traditional manufacturing process of attiéké Adjoukrou

Table 3. Frequencies of production, daily quantities and prices of different types of attiéké according to the producing ethnic Groups

Types of attiéké	Frequency of Production by Producer/6 days	Quantity (Kg/day)	Price/Kg (CFA F)
Adjoukrou	2-3	40-50	350-400
Alladjan	2-3	30-40	300-350
Ebrié Agbodjama	1	20-25	450-500
Usual Ebrié	2	40-50	250-300
Garba	5	50-60	150-200

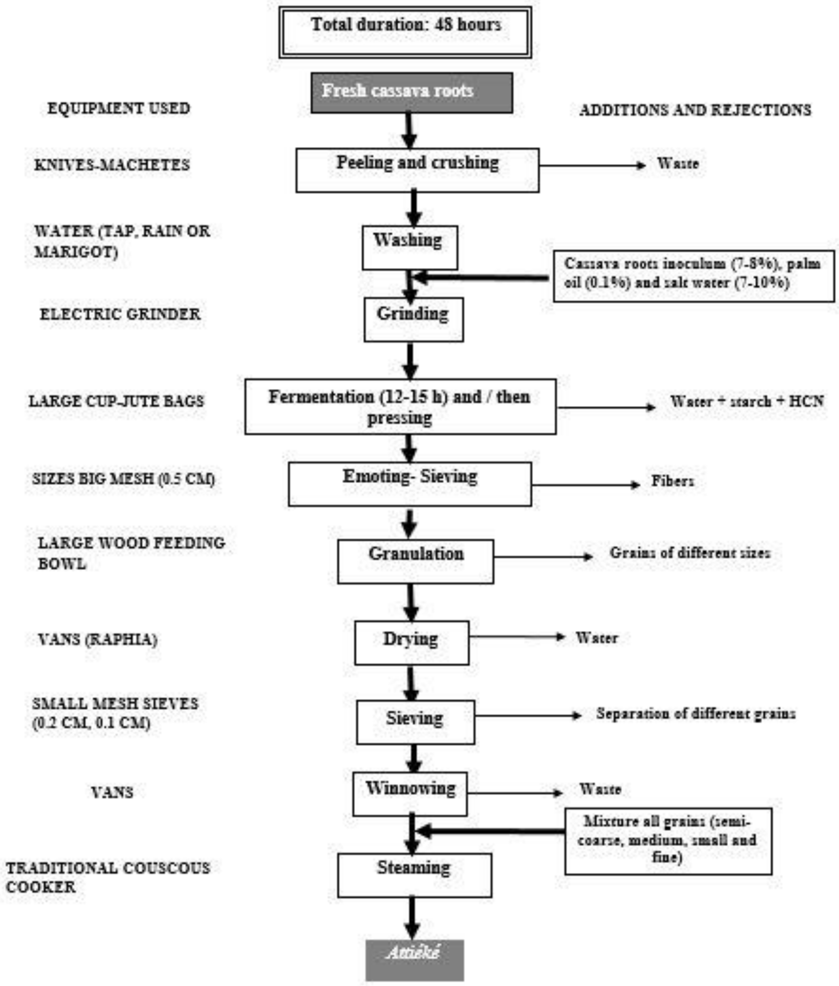

Figure 6 (b). Diagram of the traditional process of manufacturing attiéké Alladjan

3.3 Physicochemical Parameters of Inoculum and Attiéké

3.3.1 Granulometry of Attiéké

The grains size of studied attiéké can be classified in 5 categories: extra fine (Ø <0.80 mm), fine (0.80 mm ≤ Ø <1.00 mm), small (1.00 mm ≤ Ø <1.50 mm), medium (1.50 mm ≤ Ø <2.00 mm) and large (2 mm ≤ Ø <3 mm). On average, 20% of dried attiéké grains had a diameter < 1 mm, 70% had a diameter between 1 and 2 mm and 10% diameter ≥2 mm but < 3 mm.

These size ranges may vary slightly depending on the variety of cassava used, fermentation and ability to make grains easily. Garba usually had grains with diameter < 0.8 mm.

3.3.2 Physicochemical Characteristics of Inoculums from Boiled Cassava Variety IAC

There was no significant difference between cassava inoculums regardless of types of attiéké (Table 5). Only the inoculum of Garba had low rates for titratable acidity, lactic acid and acetic acid. Its pH was higher than the other inoculums (Table 4). Fresh cassava was not acid (pH = 6.01), (Table 4).

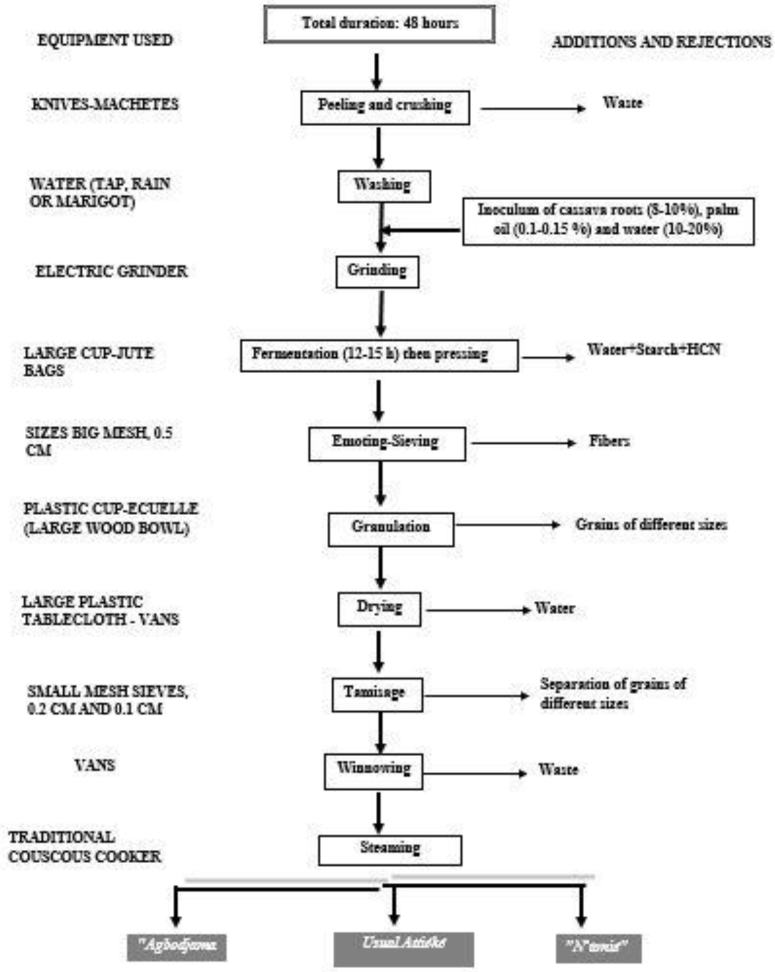

Figure 6 (c). Diagram of the traditional manufacturing process of attiéké Ebrié

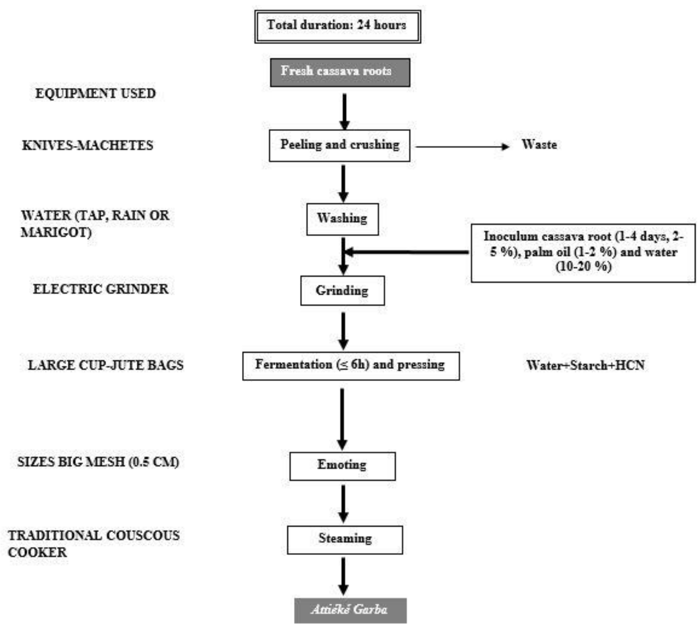

Figure 6 (d). Diagram of the traditional manufacturing process of attiéké Garba

Figure 7. Attiéké Garba packaged in a plastic bag and on a plate (Assanvo, 2008)

Table 4. Average of physicochemical characteristics of samples of boiled or fresh cassava inoculum.

Physicochemical Characteristics studied	Fresh cassava IAC Variety	Ebrié	Adjoukrou	Alladjan	Garba
	Mean ± standard deviation				
pH	6.01±0.11 a	4.9±0.03 b	5.2±0.08 b	5.3±0.04 b	5.48±0.01 c
Titratable acidity (mEq/100g)	0.1±0.01 a	0.36±0.12 b	0.33±0.05 b	0.30±0.06 b	0.25±0.07 c
Lactic acid	0.09±0.05 a	0.27±0.07 b	0.25±0.09 b	0.23±0.08 b	0.18±0.01 c
Acetic acid	0.02±0.01 a	0.08±0.03 b	0.07±0.05 b	0.08±0.02 b	0.05±0.01 c

N=36

The averages followed by the same letters in same line are not significantly different at 5%

IAC = Improved African Cassava Variety

3.3.3 Physicochemical and Biochemical Characteristics of Studied Attiéké

On average, the pH of studied attiéké was acid and varied from 4.56 (usual attiéké Ebrié) to 4.70 (attiéké Garba). This gave attiéké its acid character without being sour. The pH of attiéké Garba is the least acid. Attiéké “Agbodjama,” Adjoukrou and Alladjan had less acid pH than attiéké Ebrié and “N’tonié” which had the same pH (Table 5).

Attiéké Garba had a significant different pH ($p < 0.05$) from other attiéké.

The acidity of attiéké Garba is lower than the other studied attiéké (Table 5). Analysis of variance showed a significant difference between Garba and other types of attiéké.

The moisture content of Garba was significantly different ($p < 0.05$) from Agbodjama (43.52%), usual attiéké Ebrié (48.45%), “N’tonié” (44.55%), attiéké Adjoukrou (46.71%) and attiéké Alladjan (47.41%).

The lactic acid rate was low in all types of attiéké but was higher in usual attiéké Ebrié (1.13±0.17%). In contrast, its content in attiéké Garba remained the lowest (0.58 ± 0.16%).

The level of acetic acid was very low regardless of attiéké types (Table 5).

All biochemical parameters sought in the four studied attiéké are present in varying amounts (Table 6). At statistical level, there is a significant difference ($P < 0.05$) at least between two types of attiéké (Table 6).

The starch content was high and varied on average from 95 g/100g DM (attiéké Ebrié Agbodjama) to 78.89 g/100g DM (attiéké Garba). Analysis of variance indicated a significant difference between starch content of studied attiéké. The starch content of attiéké Garba was different ($p < 0.05$) and the lowest (Table 6).

Total sugar (1.17-1.58 g/100g DM) and reducing sugar contents of studied attiéké (0.15-0.43 g/100g DM) were very low. Attiéké Agbodjama had the highest rate (2.05±1.03 g/100g DM) while the lowest total sugar content was recorded for attiéké Garba (1.14±0.17 g/100g DM. The ANOVA indicated a significant difference ($p < 0.05$) between the 4 types of attiéké, meaning at least two attiéké were different from the others.

Table 5. Mean rate of physicochemical characteristics of 54 atti éké samples

Physicochemical characteristics studied	Agbodjama Ebri é	Usual Ebri é	N'tonié Ebri é	Adjoukrou	Alladjan	Garba
	Mean ± standard deviation					
Dry matter (%)	56.48±2.14 a	51.55±2.71 b	55.45±0.35 a	53.29±0.98 b	52.60±1.20 b	47.41±7.84 c
Humidity (%)	43.52±2.14 a	48.45±2.71 b	44.55±0.35 a	46.71±0.98 ab	47.41±1.20 b	52.59±7.84 c
pH	4.65±0.03 a	4.56±0.13 ab	4.58±0.01 ab	4.67±0.11 a	4.63±0.15 a	4.70±0.18 c
Titratable acidity (mEq/100g)	0.85±0.04 b	1.20±0.10 a	1.02±0.02 a	0.83±0.09 c	0.90±0.12 b	0.68±0.20 d
Lactic acid	0.79±0.11 a	1.13±0.17 b	0.97±0.12 b	0.77±0.23 c	0.84±0.09 a	0.58±0.16 d
Acetic acid	0.06±002 a	0.10±0.04 b	0.07±0.01 a	0.09±0.03 b	0.07±0.012 a	0.04±0.05 a

N=54, The averages followed by the same letters in same line are not significantly different at 5%

Atti éké N'toni é = atti éké Ebri é possessing small round grains of the same size

Atti éké Agodjama = atti éké Ebri é possessing round grains compared to fish eggs with substantially the same size

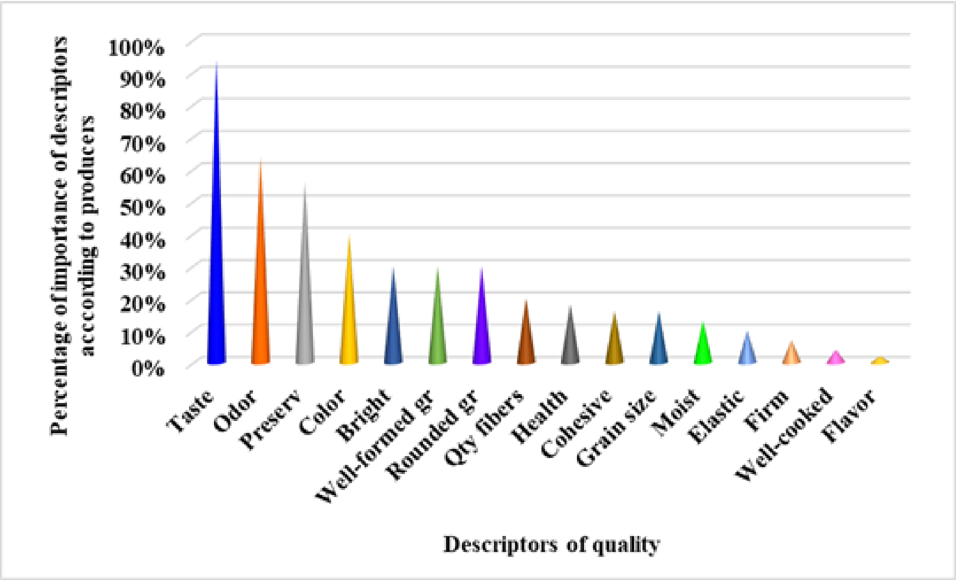

Figure 8. Importance percentages of the quality descriptors of atti éké defined by producers

Preserv: good conservation; bright aspect: translucent character; Gr well formed: well-formed grains; Rounded gr: rounded grains; Qty fibers: amount of fibers; Health: provides a well-being; cohesive: cohesion between grains; Well cooked: well-cooked atti éké

The very low reducing sugar rates ranged from 0.43±0.18 g/100g DM (atti éké Ebri é Agbodjama) to 0.15±0.66 g/100g DM (attiéké Garba). Usual attiéké Ebrié, Adjoukrou and Alladjan were not significantly different (α = 0.05%), (Table 6). Atti éké Garba had the highest contents of fiber (2.53±1.05 g/100g DM), fat (1.22±0.38 g/100g DM) and cyanide (12±2.02 g/100g DM), (Table 6). There was a significant difference between the types of atti éké studied, at least two atti éké were different from the others (Table 6).

The fat content was very low and varied from 0.057 to 1.22% of dry matter. The ash content of atti éké from cassava variety IAC was between 1.62 (atti éké Garba) and 1.90% (atti éké Adjoukrou).

Table 6. Mean rate of biochemical characteristics of 54 attiéké samples

Physicochemical characteristics studied	Agbodjama Ebrié	Usual Ebrié	N'tonié Ebrié	Adjoukrou	Alladjan	Garba
	Mean ± standard deviation					
Starch (mg/100g)	95.35±0.64 a	91.74±0.85 a	83.12±1.12 b	93.51±1.65 a	90.94±0.97 a	78.89±2.16 b
Total sugars	2.05±1.03 a	1.66 ±0.55 b	1.32 ±0.67 c	1.55 ±0.37 b	1.44 ±0.25 b	1.14 ±0.17 d
Reducing sugars	0.43 ±0.18 a	0.33 ±0.14 b	0.27 ±0.08 bc	0.35 ±0.17 b	0.30 ±1.02 b	0.15 ±0.10 c
fibers	1.15 ±0.57 a	1.43 ±0.63 b	1.10 ±0.71 a	1.56 ±0.88 c	1.48 ±0.92 b	2.53 ±1.05 d
Protein (mg/100g)	4.3 ±2.06 a	3.95 ±1.12 a	4.00 ±2.25 a	4.2 ±2.07 a	3.89 ±1.23 a	3.02 ±1.33 b
Fat (mg/100g)	0.075 ±0.02 a	0.078 ±0.04 a	0.074 ±0.05 a	0.065 ±0.08 a	0.057 ±0.035 b	1.22 ±0.38 c
Ash (mg/100g)	1.78 ±1.21 a	1.80 ±1.18 a	1.76 ±0.84 a	1.90 ±0.68 b	1.84 ±1.07 c	1.62 ±1.05 d
Cyanide (mg/100g)	4.95 ±1.01 a	5.18 ±1.51 a	4.62 ±0.78 b	3.88 ±1.03 c	3.52 ±1.15 c	12 ±2.02 d

N = 54, The averages followed by the same letters in one line are not significantly different at 5%

Attiéké Ntonié =attiéké Ebrié possessing small round grains of the same size

Attiéké Agodjama = attiéké Ebrié possessing round grains compared to fish eggs with substantially the same size

The protein contents ranged between 3.02±1.33 g/100g DM (attiéké Garba) and 4.3 ± 2.06 g/100g DM (attiéké Ebrié Agbodjama). There was a significant difference between attiéké Garba and other types of attiéké that had similar level of protein.

3.3.4 Production Yield of the 4 Types of Attiéké

The final yield of attiéké production showed that cassava variety IAC had the highest value for attiéké Garba (38.07%), and the lowest (31.93%) for attiéké Alladjan. However, the yield of attiéké Alladjan was close to that of attiéké Adjoukrou (32.42%) and usual attiéké Ebrié (33.83%).

The fiber content is higher in attiéké Garba compared to other types of attiéké and ranges from 1.10±0.71g/100g DM (″N'tonié″) to 2.53±1.05 g/100g DM for the Garba.

4. Discussion

4.1 Influence of Traditional Attiéké Production Technologies on Its Quality

4.1.1 Technological Process of Attiéké and Constraints Related to Food Chain (from Cassava to Consumer)

The results on the impact of cassava variety and inoculum on the quality of traditional attiéké confirmed those of Kouadio, Kouakou, Angbo and Mosso (1991) focused on traditional preparing methods of attiéké in Southern Côte d'Ivoire. The traditional manufacturing methods of inoculum and attiéké, preserving the finished product are similar to a few nuances. Nowadays, great similarities were observed because of cultural mix and growing demand. The consequence of this increasing demand is reduction of the time of manufacturing process. This time rose to 12-15 hours while it was 1-2 days according to Kouadio et al. (1991). Also, the proportion of inoculum varies depending on cassava variety used (quantity and quality). Appreciation of the end and quality of fermentation has remained the same, using the touch (Kouadio et al., 1991). The semolina obtained following modification of dough texture during fermentation, will facilitate shaping of small granules with capacity to absorb a large amount of water (Assanvo et al., 2006). According to Moorthy and Mathew (1998) and McFeeters (2008), lactic acid bacteria, main agents of fermentation of cassava paste, contribute to the texture, flavor, and production of aromatic compounds. Grinding facilitates fermentation, suppressing cellular structures, homogenizing the environment and promoting development of microorganisms (Mescle & Zucca, 1996). For beneficial impact of this step on attiéké quality (Anonymous 2, 2005), ensuring best conditions is important for this process.

The adjustments in manufacturing attiéké Garba may lead to serious consequences on consumers' health. Risks are associated with cyanide residues in the finished product due to reduction in fermentation time of bitter cassava (Assanvo, Agbo, & Farah, 2019).

In the case of attiéké Garba, some steps such as granulation and drying are removed and cooking time is reduced. However, these steps help eliminating cyanide. Zacarias, Esteban, Rodrigues, & de Souza Nascimento (2017) confirm fears and possible exposure to cyanide may be predicted. Heuberger (2005) support these results suggesting cyanide compounds less than 10 mg/kg may be considered safe for consumption. According to Obilie, Tano-Debrah and Amoa-Awua (2004), attiéké produced in Southwestern Ghana ("akyeke") is not at risk of toxicity because all steps of the manufacturing process are followed. Cyanide in "akyeke" is very low (1.4-2.8

mg CN equivalent/kg dry matter) and the cassava varieties used are sweet (69.3-110 mg CN equivalent/kg dry matter).

Cassava variety also has impact on the color of attiéké as different colors were observed for the different types studied. According to Sotomey Ategbo, Mitchikpe, Gutierrez and Nago (2001), colors of attiéké most often depend on cassava varieties, moisture of rolled dough and amount of palm oil. New cooked attiéké has a color ranging from yellowish to whitish or dark, cream color is preferred in Côte d'Ivoire. The color darkens more 3-5 days post preparation with quality deterioration. Bavaro et al. (2017), reported molds are responsible for dark color following spontaneous fermentation. Also the presence of oil could causes a slight oxidation.

Food packaging should allow food reaching consumers under optimal conditions (Anonymous 3, 2006). Packaging helps maximizing the life of products, carrying this important information on the label (Anonymous 3, 2006). At the moment, the types of packaging used by producers is not a guaranty of safety, no scientific study determines their quality.

4.1.2 Importance of Quality Descriptors of Attiéké According Producers

Quality attributes are of paramount importance in the assessment of attiéké by producers (Assanvo, Agbo, Brunnchweiler Beez, Monsan, & Farah, 2018). The descriptor taste is capital in the choice of a good attiéké. Slightly acid taste is sought by producers. Attiéké can have a sweet taste regardless of acidity or even a neutral flavor due to sugars responsible for the flavor of fermented foods (Bourdichon et al., 2012). Lactic acid and acetic acid (Coulin, Farah, Assanvo, Spillmann, & Puhan, 2006) have a very high perception threshold and have an impact on organoleptic qualities due to their high concentrations (Bourdichon et al., 2012). Organic acids derived from glycolysis are important precursors of aromas. Odor is the second attribute in the choice of producers followed by the "long life" descriptor (56%). Both descriptors (odor and taste) are benchmarks for producers in assessing the quality of finished products. In addition, Maille (2003) showed that unpleasant odors had a negative impact on sale outlets.

Producers also appreciated good attiéké when well cooked. Indeed, the conservation of attiéké is very often linked to the well-cooked character. Cooking is a very important step, and has an impact on storage, hygienic and toxic qualities of attiéké.

Color and bright appearance appear as important descriptors in producer's appreciation. Attiéké must have a shine due to translucent nature. Color plays an important role in assessing the quality and first impressions of a food in terms of maturity, impurities, appropriate or defective technological treatment, poor storage conditions, an early microbial deterioration (Nout, Hounhouigan, & Boekel, 2003). Ebrié prefer the off-white color, Adjoukrou and Alladjan the light yellow (or cream) color.

The other descriptors such as fiber, well-being, grain size, moisture, firmness, and flavour, appear secondary but had some importance. Attiéké Garba differs from usual attiéké by presence of fibers. The term "provides a well-being" puts more emphasis on hedonic characters (pleasure felt) of food.

The moisture of attiéké must not be beyond the desired limit since it should neither be perceived as wet or dry. Traditional producers indicated importance of feeling firmness and graininess of attiéké grains. In conclusion, all quality attributes are important for producers.

4.1.3 Consequence of Attiéké Quality on Price and Frequency of Production

The attiéké quality influences its selling price and production frequency. The more the manufacturing processes are shortened and poorly executed, the less expensive is attiéké and the more the quantity produced/day/week is high. The production of Garba is related to growing demand and relative high cost of other types of attiéké (Assanvo et al., 2019). Three main reasons support its consumption: very low cost, large quantity served and especially energy supply.

Attiéké agbodjama and usual attiéké were respectively two-fold or one and half-fold as expensive as attiéké Garba. "Agbodjama" is the most expensive attiéké because its manufacturing requires too time and great efforts for granulation and winnowing. The prices of attiéké on markets of Abidjan vary often according to seasons. In rainy season, these prices increase related to drying difficulties.

4.2 Physicochemical Characteristics of Attiéké Types

4.2.1 Influence of Fermentation on the Quality of Different Types of Attiéké

The use of IAC variety for producing attiéké in the three regions surveyed allows assessing the impact of inoculum on organoleptic quality of attiéké. The physicochemical analysis confirmed the statements of producers. Whatever the attiéké, lactic and acetic acids were present and affected the acidulous taste and aroma. The rates of these acids in traditional attiéké and Garba were low but indicated that the fermentation is heterolactic due to actions of traditional cassava inoculum.

The starch content of attiéké agbodjama is higher than all other attiéké produced because the producers take the time to enlarge, round and harden the grains. However, high amount of starch is due to incomplete release and lost during fermentation (Hatew et al., 2015).

Total and reducing sugar rates were low but highest in attiéké from well fermented doughs. Bad fermentation may explain their lowest rate in Garba.

4.2.2 Influence of Manufacturing Process on Production Yield

Several factors influence the performance of production. Losses occur throughout the manufacturing process and vary depending on the step. Among those having the greatest impact were peeling, crushing, grinding, pressing and winnowing (Nago, 1995). Losses recorded were up to 66.17% for attiéké Ebrié, 67.58% for attiéké Adjoukrou, 68.07% for attiéké Alladjan and 61.93% for attiéké Garba. In terms of yield, attiéké Garba (around 34%) appears more profitable since many losses are minimized as possible.

Yield may be related to useful material (cassava variety). The higher the dry matter in a variety, the more variety gives a lot of attiéké. According to Njukwe, Hanna, Kirscht, & Araki (2013), the main criteria for choosing a variety is obviously its productivity in dry matter or starch. The age of harvest also can influence the yield of transformation.

5. Conclusion

Surveys of production showed that cassava inoculum is being prepared similarly in all three regions visited. For producers, cassava variety does not matter for a good inoculum which has a decisive impact on fermentation of fresh paste. It lightenes the dough for a better ability to form grains (semolina) and imposes desired taste and smell of attiéké. Making a good attiéké is correlated with some attributes of quality. A good attiéké has a slightly acid and sweet taste, a very characteristic smell and aroma of fermented cassava found pleasant, at least one week lifespan, a bright color, a spongy character expressing a cohesive and elastic texture. The firm and granular texture is appreciated during the appetizer. Attiéké Garba does not meet these characteristics and consumers may be at risk due to cyanide. Future investigations are needed for reducing cyanide in this product.

The control of external factors as immediate working environment, temperature, humidity, seasons can improve the quality of attiéké.

Acknowledgments

The authors thank the Laboratory of Biochemistry and Food Sciences (University FHB, Côte d'Ivoire), the Institute of Food Science of the Federal Polytechnic School of Zurich (Switzerland), the Swiss Center for Scientific Research in Côte d'Ivoire and the International Foundation for Science (IFS) for their technical and financial support.

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